WATER QUALITY MONITORING:
Interim Field Guide
R-3, 1970

March 1968
Revised 1/70

R-3
R.O. 2540

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

Interim

Field Guide

WATER QUALITY MONITORING

R-3
USFS

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Interim

Field Guide

WATER QUALITY MONITORING

R-3
USFS

Compiled by

H. J. McKirdy

June 1968

FOREWORD

The Water Quality Act of 1965 and Executive Order No. 11288 of 7/2/66 assigned Federal Agencies responsibility for carrying out specific activities in Water Pollution Control. One part of the Forest Service task is Water Quality Monitoring. (Refer R-3 Supplement No. 1, March 1968, 2540).

R-3 has started a modest program of Water Quality Monitoring at selected stations. Full implementation will depend on funds and program direction from the Chief's Office.

The instructions contained in this interim Field Guide were compiled by H. J. McKirdy to assist Watershed Scientists. This guide assembles in one place the important directives and procedures for making the surveys and evaluating your findings.

A servicewide handbook is being prepared. This interim guide should be followed until new instructions are received.

Lowell G. Woods

WATER

Water is a common denominator that ties together all of man's interests. On its journey from watershed to sea, it will affect fishing downstream, recreation on a man-made lake, irrigation on a valley farm, flood damage in a community, quality of water for industry and safe supplies for human use.

Pollution from sewage and industrial wastes, and mine drainage, pesticide chemicals, and other contaminants that enter the stream at any point may have far reaching effects throughout the watershed. At this point one might ask: Which is most important - the water needs of man or the water needs of fish? Actually, both must be provided. In many cases the fisherman may be most immediately affected by pollution, but when water no longer supports fish it has lost much of its value for other uses, too.

Fish are good indicators of water quality. When an area no longer supports fish it has lost much of its livability for people as well. Areas with extensive water pollution often are characterized by low levels of economic activity simply because the people fail to understand the relationships between their aspirations and nearby water. (SFI Sept. 1965)

PURPOSE

The purpose of this guide is to assemble in one place, information and instructions to aid the Staffman in the Water Quality Monitoring Program of Region 3.

In the back of the guide is a list of recommended reference material which can be purchased or requested from the listed source.

As improved methods, techniques, materials, research and management direction becomes available it will be distributed for insertion in this guide. This information has been compiled from many sources and is believed to be the best and most recent data available.

We hope it will help you in your monitoring efforts.

INTRODUCTION

As a part of this Region's responsibilities; to meet the water quality standards as approved by the Federal Water Pollution Control Administration; to fulfill our role as specified in the Presidential Executive Order #11288; and the Memorandum of Agreement between the Chief, U. S. Forest Service and Commissioner, FWCA, a program to monitor water quality has been inaugerated.

In order to reaffirm our interest in and our intent to effectively contribute to the maintenance of a quality of water necessary to accommodate the various uses of the water resources, realizing that watershed use results in water quality changes and that each user has a responsibility to downstream users, it becomes necessary to establish these monitoring stations near our Forest boundaries. Other stations, depending on use, are to be selected near heavy recreation areas, summer home areas, mining activity areas, road construction, timber sale areas, and other areas of use which may affect the water quality.

It should be fairly obvious that water quality needs may differ widely with different water uses. What may be satisfactory for one use, could constitute pollution for another use. Unless corrective measures for upstream water uses have been taken, the downstream quality will continue to deteriorate until it no longer is suited for a particular use.

Recent information tells us that water in the United States is presently five (5) times greater than the amount used. This brings up the question, then, how can we have water shortages? There are three (3) main reasons for a water shortage: <u>Distribution</u>, <u>Time</u>, and <u>Improper Use</u>.

Distribution - Parts of the country such as portions of the Pacific NW receive 120 inches per year, other sections such as portions of our own Southwest receive as little as five inches per year.

Time - Much of the precipitation falls during wet periods when waterlogged earth can no longer soak it up.

Improper Use - Waste.

What can be done to improve these water shortages?

1. Transportation - This is being done by means of tunnels, canals, diversion ditches, etc.

2. Conserve - This is being done by damming up streams (reservoirs), and increasing yield.

3. Eliminate waste due to pollution - This is the main reason for a water quality monitoring program of this type. It is a program which has been thought about for many years, but has not as yet been fully developed.

Due to natural conditions such as various geological formations not all water quality in the Region will be the same. Those changes in water quality due to the various uses by man are the ones to be considered and analyzed for corrective measures as may be indicated from the results of this monitoring program.

The following pages are for your use and guidance in developing a desirable water quality program and will also help in evaluating the needs of various uses as pertains to water quality. Hopefully, this preliminary guide will provide the tool necessary in initially setting-up this program. As new ideas, methods, procedures and suggestions from the field develop, a better and more useful guide can be assembled.

EXECUTIVE ORDER 11288

PREVENTION, CONTROL, AND ABATEMENT OF WATER POLLUTION BY FEDERAL ACTIVITIES

By virtue of the authority vested in me as President of the United States and in furtherance of the purpose and policy of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466), and Reorganization Plan No. 2 of 1966 (31 F.R. 6857), it is ordered as follows:

SECTION 1. *Policy.* The heads of the departments, agencies, and establishments of the Executive Branch of the Government shall provide leadership in the nationwide effort to improve water quality through prevention, control, and abatement of water pollution from Federal Government activities in the United States. In order to achieve these objectives—

(1) Pollution from all existing Federal facilities and buildings shall be controlled in accordance with plans to be submitted to the Director of the Bureau of the Budget pursuant to Section 3 of this order;

(2) New Federal facilities and buildings shall be constructed so as to meet the pollution control standards prescribed by Section 4 of this order;

(3) Pollution caused by all other operations of the Federal Government, such as water resources projects and operations under Federal loans, grants, or contracts, shall be reduced to the lowest level practicable;

(4) Review and surveillance of all such activities shall be maintained to assure that pollution control standards are met on a continuing basis;

(5) The Secretary of the Interior shall, in administering the Federal Water Pollution Control Act, as amended, provide technical advice and assistance to the heads of other departments, agencies, and establishments in connection with their duties and responsibilities under this order;

(6) The head of each department, agency, and establishment shall ensure compliance with Section 11 of the Federal Water Pollution Control Act, as amended (33 U.S.C.. 466h), which, as modified by Reorganization Plan No. 2 of 1966 (31 F.R. 6857), declares it to be the intent of Congress that Federal departments and agencies shall, insofar as practicable and consistent with the interests of the United States and within available appropriations, cooperate with the Secretary of the Interior and with State and interstate agencies and municipalities, in preventing or controlling water pollution; and

(7) Water pollution control needs shall be considered in the initial stages of planning for each new installation or project, and the head of each department, agency, and establishment shall establish appropriate procedures for securing advice and for consulting with the Secretary of the Interior at the earliest feasible stage.

SEC. 2. *Procedures for new Federal facilities and buildings.* (a) A request for funds to defray the cost of designing and constructing new facilities and buildings in the United States shall be included in the annual budget estimates of a department, agency, or establishment only if such request includes funds to defray the costs of such measures as may be necessary to assure that the new facility or building will meet the general standards prescribed by Section 4 of this order.

(b) Prior to any solicitation of bids for construction of any such new facility or building a description of the essential features of the water pollution control and treatment measures proposed for the project shall be submitted to the Secretary of the Interior for prompt review and advice as to the adequacy and effectiveness of the measures proposed and for advice as to any related operating procedures and continuing laboratory examinations deemed necessary to ensure effective plant operation.

SEC. 3. *Procedures for existing Federal facilities and buildings.* (a) In order to facilitate budgeting for corrective and preventive measures, the head of each department, agency, and establishment shall provide for an examination of all existing facilities and buildings under his jurisdiction in the United States and shall develop and present to the Director of the Bureau of the Budget, by July 1, 1966, a phased and orderly plan for installing such improvements as may be needed to prevent water pollution, or abate such water pollution as may exist, with respect to such buildings and facilities. Subsequent revisions needed to keep any such plan up-to-date shall be promptly submitted to the Director of the Bureau of the Budget. Future construction work at each such facility and the expected future use of the facility shall be considered in developing such a plan. Each such plan, and any revisions therein, shall be developed in consultation with the Secretary of the Interior in order to ensure that adoption of the measures proposed thereby will result in the prevention or abatement of water pollution in conformity with the general standards prescribed by Section 4 of this order.

(b) The head of each department, agency, and establishment shall present to the Director of the Bureau of the Budget, by July 1, 1967, and by the first of each fiscal year thereafter, an annual report describing the progress of his department, agency, or establishment in accomplishing the objectives of its pollution abatement plan.

SEC. 4. *General standards.* (a) Federal installations shall provide secondary treatment, or its equivalent, for all wastes except cooling water and fish hatchery effluents. Discharge of wastes into municipal sewerage systems maintaining adequate treatment is hereby declared to be the preferred method of disposal. However, whenever connection to such a system is not feasible, the department, agency, or establishment concerned shall be responsible for installing its own waste treatment system. Upon an application of the head of a department, agency, or establishment, a degree of treatment less than secondary may be approved with respect to an agency-installed system in an exceptional case if the Secretary of the Interior finds that a lesser degree of treatment is adequate to protect the quality of the receiving waters.

(b) If discharge of cooling water is expected to create problems by significantly increasing the temperature of the receiving waters, facilities shall be installed, or operating procedures shall be established, to maintain water temperatures within acceptable limits.

(c) Storage facilities for materials which are hazardous to health and welfare, and for oils, gases, fuels or other materials capable of causing water pollution, if accidentally discharged, shall be located so as to minimize or prevent any spillage which might result in water pollution. Engineering measures to entrap spillage, such as catchment areas, relief vessels, or entrapment-dikes, shall be installed so as to prevent accidental pollution of water.

(d) No waste shall be discharged into waters if it contains any substances in concentrations which are hazardous to health.

(e) No waste shall be discharged into waters if it contains any substances in concentrations which will result in substantial harm to domestic animals, fish, shellfish, or wildlife, if methods of treatment or disposal are available that will remove or render harmless such pollutants. If such methods are not available, but can reasonably be developed, they will be developed and used at the earliest possible date. A determination that such methods are not available or cannot reasonably be developed will not be made without the concurrence of the Secretary of the Interior.

(f) The head of each department, agency, and establishment shall, with respect to each installation in the United States under his jurisdiction, make, or cause to be made, such surveys as may be necessary to ensure that discharges of waste effluents from activities concerned with radioactivity are in accord with the applicable rules, regulations, or requirements of the Atomic Energy Commission (10 CFR, Part 20) and the policies and guidance of the Federal Radiation Council as published in the FEDERAL REGISTER.

(g) Construction and operating plans for waste treatment facilities shall include space for the conduct of necessary laboratory analyses and for the maintenance of records of results thereof whenever the size and complexity of the system makes this necessary.

(h) Construction and operating plans for waste treatment facilities shall take into account water quality standards promulgated pursuant to the provisions of the Water Quality Act of 1965 (79 Stat. 903).

(i) Any waste treatment facilities installed by any department, agency, or establishment shall as far as practicable be constructed so as to conform with any areawide program, meeting criteria established by the Secretary of Housing and Urban Development for a unified or officially coordinated areawide sewer facilities system as part of the comprehensively planned development of the area pursuant to Section 702(c) of the Housing and Urban Development Act of 1965, that may have been adopted with respect to the area concerned.

SEC. 5. *Modification of standards.* The standards prescribed by paragraphs (a) through (e) and (g) through (i) of Section 4 of this order may be supplemented or modified by the Secretary of the Interior, after consultation with the Director of the Bureau of the Budget. All such changes shall be published in the FEDERAL REGISTER.

SEC. 6. *Procedures for Federal water resources projects.* (a) The Secretaries of Agriculture and the Army, the Tennessee Valley Authority, and the United States Section of the International Boundary and Water Commission shall present for the consideration of the Secretary of the Interior any plans that they propose to recommend with respect to the authorization or construction of any Federal water resource development project in the United States. Such plans must be consistent with the general standards prescribed by Section 4 of this order to the fullest extent practicable. The Secretary of the Interior shall review such plans and supporting data relating to water quality, and shall prepare a report to the head of the responsible department, agency, or establishment describing the potential impact of the project on water quality, including recommendations concerning any changes or other measures with respect thereto which he considers to be necessary with respect to the design, construction, and operation of the project.

(b) The report of the Secretary of the Interior shall accompany any report proposing authorization or construction of such a water resource development project. In any case in which the Secretary of the Interior fails to submit a report within 90 days after receipt of project plans, the head of the department, agency, or establishment concerned may propose authorization or construction of the project without such an accompanying report. In any such case, the head of the department, agency, or establishment concerned shall explicitly state in his report concerning the project that the Secretary of the Interior has not reported on the potential impact of the project on water quality.

SEC. 7. *Review of facilities or operations supported by Federal loans, grants, or contracts.* (a) The head of each department, agency, and establishment shall conduct a review of the loan, grant, and contract practices of his organization to determine the extent to which water pollution control standards similar to those set forth in this order for direct Federal operations should be adhered to by borrowers, grantees, or contractors with respect to their operations in the United States. The head of each department, agency, and establishment

shall review all such activities for which there is a significant potential for reduction of water pollution and develop appropriate recommendations for accomplishing such reduction. In conducting this review, necessary technical assistance should be sought from the Secretary of the Interior and the heads of other appropriate Federal agencies. A report on the results of this review shall be submitted to the Director of the Bureau of the Budget by July 1, 1966.

(b) The heads of departments, agencies, and establishments are encouraged to prescribe regulations covering loan, grant, or contract practices designed to reduced water pollution.

SEC. 8. *Study of water pollution from vessel operations.* The Secretary of the Interior shall make a comprehensive study of the problem of water pollution within the United States caused by the operation of vessels, and shall develop such recommendations for corrective or preventive action as may be appropriate, including recommendations with respect to vessels operated by any department, agency, or establishment of the Federal Government. The results of the study and recommendations shall be transmitted to the President by January 1, 1967. The study and report thereon shall be prepared in consultation with, and with the advice and assistance of, the Secretary of Defense, the Secretary of the Treasury, the Secretary of Commerce, and the Secretary of Health, Education, and Welfare.

SEC. 9. *Prior Executive order superseded.* Executive Order No. 11258 of November 17, 1965, is hereby superseded.

LYNDON B. JOHNSON

THE WHITE HOUSE,
July 2, 1966.

[F.R. Doc. 66-7460; Filed, July 5, 1966; 4:46 p.m.]

MEMORANDUM OF AGREEMENT

*-1531.8 - Federal Water Pollution Control Administration. There follows a memorandum of agreement between the Chief of the Forest Service and the Commissioner of the Federal Water Pollution Control Administration for the prevention, control, and abatement of water pollution from facilities and buildings on National Forest System lands, and activities administered by the Forest Service.

The purpose of this memorandum is to establish and record agreed upon principles and policies of collaboration and coordination with respect to maintaining or enhancing water quality through prevention, control, and abatement of water pollution from Federal activities in the United States and to establish means and procedures to collaborate, develop, and cooperate in administrative and research projects.

Executive Order 11288 of July 2, 1966, states:

"The heads of the departments, agencies, and establishments of the Executive Branch of the Government shall provide leadership in the nation-wide effort to improve water quality through prevention, control, and abatement of water pollution from Federal Government activities in the United States. In order to achieve these objectives:

(1) Pollution from all existing Federal facilities and buildings shall be controlled in accordance with plans to be submitted to the Director of the Bureau of the Budget pursuant to Section 3 of this Order;

(2) New Federal facilities and buildings shall be constructed so as to meet the pollution control standards prescribed by Section 4 of this Order; -*

*- The Forest Service has established policies, procedures, standards, and designs and equipped itself with the basic scientific and engineering capabilities to effectively achieve the water quality objectives of Executive Order 11288. To the extent of budgetary limitations, the Forest Service is conducting a continuing program to install or require the installation of waste treatment facilities where necessary and is conducting activities under its jurisdiction in furtherance of these objectives.

The Federal Water Pollution Control Administration, U.S. Department of the Interior, is responsible for:

1. Providing technical advice and assistance to the heads of other departments, agencies, and establishments in connection with their duties and responsibilities under this Order.

2. Providing prompt review and advice as to the adequacy and effectiveness of water pollution control and treatment measures, their operation, and continuing laboratory examination deemed necessary to ensure effective plant operation for new facilities and buildings.

3. Providing consultation to the head of each department, agency, and establishment on corrective and preventive measures for water pollution control at existing facilities and buildings to ensure conformity with the general standards prescribed by Section 4 of the Order.

4. Approving a degree of treatment less than secondary, upon application by the head of a department, agency, or establishment, for the agency installed system in an exceptional case, providing the findings are that a lesser degree of treatment will adequately protect the quality of the receiving water.

5. Determining if methods of treatment and disposal are available for waste containing substances in concentrations which will result in substantial harm to domestic animals, fish, shellfish or wildlife.

6. Approving and/or adopting water quality standards promulgated pursuant to the provisions of the Water Quality Act of 1965 (79 Stat. 903).

7. Modifying standards prescribed by paragraphs (a) through (e) and (g) through (i) of Section 4 of the Order. -*

*- 8. Reviewing plans and supporting data to determine the potential impact on water quality of water resources projects proposed to be recommended for authorization or construction by the Secretaries of Agriculture, the Army and the Interior; the Tennessee Valley Authority, and the U.S. Section of the International Boundary and Water Commission for consistency with the general standards of Section 4 of the Order and potential impact on water quality, and making recommendations with respect to design, construction, and operation of the projects.

9. Providing technical assistance to departments, agencies, and establishments in the review and application of standards similar to those set forth in the Order for water pollution control for facilities or operations supported by Federal loans, grants or contracts.

10. Developing recommendations with respect to corrective or preventive water pollution control measures for vessels operated by any agency of the Federal Government.

It is, therefore, agreed that to implement and facilitate achievement of these responsibilities:

1. The Forest Service will:

(a) Provide the FWPCA with sets of standard sample designs and pertinent information relative to installation and operation of non-water carriage systems used for control of waste discharge and disposal on National Forest System lands.

(b) Provide the FWPCA for review and advice prior to solicitation of construction bids for Federal facilities and buildings, a description of the essential features of water pollution control and treatment measures proposed for facilities where such facilities involve design features not covered in 1(a) above and effluent will be discharged into surface or ground waters.

(c) Maintain a regular inspection and record of activities and individual facilities producing waste which will enter surface or ground water. This will include a continuing periodic sampling and analytical program as needed to determine the physical, chemical, and biological characteristics of waste effluents and the effectiveness of waste disposal facilities in meeting water quality standards approved by FWPCA. Make available on a written request from FWPCA technical records covering the effectiveness of waste treatment and disposal from selected water carriage systems where the potential threat to water quality is significant. -*

*- (d) Maintain regular inspection and on a sampling basis, a monitoring system and analytical program to determine the significant physical, chemical, and biological characteristics of the water resources within National Forest watersheds and of return flows at selected sites for the purpose of identifying emerging National Forest water quality management problems.

(e) Provide samples of loan, grant, and contract regulations for prevention of water pollution.

2. The FWPCA will:

(a) Consult with and provide technical advice and assistance in solution of complex pollution prevention, control or abatement problems associated with Forest Service facilities, activities, and buildings.

(b) Assist in preparing and maintaining a list of laboratories qualified to evaluate from samples the characteristics of water and waste effluents.

(c) Provide consultation and recommendations on improvements needed to prevent or abate water pollution through review of plans at new facilities and revisions for existing facilities.

(d) Review the technical features of water quality monitoring and surveillance from representative sample watersheds or where there is evidence of a significant change in quality of the water or a major change in downstream water uses.

3. The Forest Service and FWPCA will:

(a) Review annually the Forest Service programs of loans, grants, and contracts, and for prevention, control or abatement of water pollution from existing and proposed activities, i.e., sewage, chemicals, sediment, pesticides, having a significant effect on water quality. Such reviews to be held by representatives of the Regional Directors for FWPCA and the Regional Forester for the Forest Service, not later than May 15 of each year. X

(b) Develop a mutually acceptable plan of work to include field surveys and Forest Service requests for advice and assistance on complex pollution problems. ok

(c) Develop a schedule for submission and review of water resource development and other projects requiring the review and advice of FWPCA. -* X

*- (d) Identify areas where cooperative administrative studies and demonstration areas or research projects can be mutually beneficial and prepare supplemental memorandum of agreement to define the project purpose and the contribution of personnel, equipment, funds, and supplies each shall make to the project. The Regional Forester, Area Director, or Station Director for the Forest Service and the Regional Director for FWPCA are delegated authority to negotiate and sign supplemental agreements under the legal, fiscal, and other limitations governing each.

Signed at Washington, D. C., this 18th day of July, 1967.

Forest Service, USDA	Federal Water Pollution Control Administration
By /s/ Edward P. Cliff Chief	By /s/ James M. Quigley Commissioner -*

2542 - NATIONAL FOREST SYSTEM WATER-USE QUALITY

2542.01 - Authority. As a result of the Water Quality Act of 1965, Executive Order No. 11288 was issued by the President, July 2, 1966, entitled "Prevention, Control, and the Abatement of Water Pollution by Federal Activities." The functions of this Executive Order, previously assigned to the Secretary of Health, Education, and Welfare are now assigned to the Secretary of Interior. Specific functions are assigned by the Department of Interior (Federal Water Pollution Control Administration) to the Department of Agriculture (U.S. Forest Service) in a Memorandum of Agreement dated July 18, 1967, between the Commissioner, FWPCA and the Chief, USFS. (FSM 1531.8)

2542.02 - Objective. These functions in part, which pertain to the Forest Service are:

1. Provide the FWPCA with sets of standard sample designs relative to installation and operation of non-water carriage systems on National Forest System lands.

2. Provide the FWPCA for review and advice a description of essential features of water pollution control and treatment measures not covered in item 1 above and where effluent will be discharged into surface or ground waters.

3. Maintain a regular inspection and record of activities and individual facilities providing waste which will enter surface or ground water.

4. Maintain regular inspection and, on a sampling basis, a monitoring system and analytical program to determine the physical, chemical, and biological characteristics of the National Forest water resources.

5. Provide samples of loan, grant, and contract regulations for the prevention of water pollution.

2542.04 - Responsibility

1. Regional Forester. To meet the Southwest Region's responsibilities for carrying out the Forest Service assignment of the Executive Order No. 11288 and the Memorandum of Agreement, dated July 18, 1967, for the Prevention, Control and Abatement of water pollution from facilities and buildings on National Forest System lands and activities administered by the Forest Service the following Regional responsibilities are assigned:

a. Division of Watershed Management, State and Private Forestry. Because the Water Quality Act and the Executive Order are broad in their relationship to the whole area of water quality management and will affect many National Forest programs, the responsibility for negotiating interagency agreements, as well as liaison and coordination with other agencies at the Regional level, is assigned to the Division of Watershed Management, State and Private Forestry. This Division also has primary responsibility to develop and implement a coordinated Regional water-quality monitoring program to assure that pollution control standards are met. This will be done on representative sample watersheds or where there is evidence of a significant change in quality of the water or a major change in downstream water uses. Responsibility for this task is presently assigned to the Regional fishery biologist but with technical direction from the Division of Watershed Management-State and Private Forestry. The Regional fishery biologist is assigned to the Division of Range and Wildlife Management.

Water Qual.

b. Division of Range and Wildlife Management. The Division of Range and Wildlife will have responsibilities for providing standards and technical skills relative to water quality as it affects fish, waterfowl, and other aquatics. This Division will coordinate with the U.S. Fish and Wildlife Service all monitoring programs on National Forest lands in regard to pesticide programs. To prevent duplication of effort the Division of Range and Wildlife will coordinate its water monitoring activities with the Division of Watershed Management-State and Private Forestry.

Fish & W.L.

c. Division of Engineering. This Division will provide the FWPCA with sets of standard sample designs and pertinent information relative to installation and operation of non-water carriage systems used for control of waste discharge and disposal on National Forest System lands. They will also provide the FWPCA, for review and advice, a description of the essential features of water-pollution control and treatment measures proposed for facilities not included in the standard design and a sample of loan, grant, and contract regulations for the prevention of water pollution. The Division of Engineering will also maintain a regular inspection and record of activities and individual facilities providing waste which will enter surface or ground water. This will include a continuing periodic sampling and analytical program of waste effluent characteristics.

Waste

d. The Divisions of Watershed Management-State and Private Forestry and Engineering will:

(1) Meet with the FWPCA and review annually Forest Service programs for prevention, control, and abatement of water pollution from existing and proposed activities--i.e., sewage, chemicals, sediment, pesticides--having a significant effect on water quality. Such review is to be held by representatives of the Regional Directors for Federal Water Pollution Control Administration and the Regional Forester for the Forest Service not later than May 15 of each year.

(2) Develop a mutually acceptable plan of work to include field surveys and National Forest requests for advice and assistance on complex pollution problems for participation with the FWPCA.

(3) Develop a schedule for submission and review of water resource development and other projects requiring the review and advice of FWPCA.

(4) Identify areas where cooperative administrative studies and demonstration areas or research projects can be mutually beneficial and prepare supplemental memorandum of agreement to define the project purpose and the contribution of personnel, equipment, funds, and supplies each shall make to the project.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Region 3

REPLY TO: 2540 - Water Uses and Development December 17, 1968

SUBJECT: Water Quality Standards

TO: Forest Supervisors

In regard to State water quality standards, the Secretary of Interior is requiring a degradation clause which will be substantially in accordance with the following:

> "Waters whose existing quality is better than the established standards as of the date on which such standards become effective will be maintained at their existing high quality. These and other waters of your State will not be lowered in quality unless and until it has been affirmatively demonstrated to the State water pollution control agency and the Department of the Interior that such change is justifiable as a result of necessary economic or social development and will not interfere with or become injurious to any assigned uses made of, or presently possible in, such waters. This will require that any industrial, public or private project or development which would constitute a new source of pollution or an increased source of pollution to high quality waters will be required, as part of the initial project design, to provide the highest and best degree of waste treatment available under existing technology, and, since these are also Federal standards, these waste treatment requirements will be developed cooperatively."

Since the forests in this region produce and provide the bulk of the water resource for use in Arizona and New Mexico, the above clause is probably one that will effect our work most. Kindly be guided by the above in the job of monitoring our waters and in planning new projects and activities.

J W Kaskella, For

Wm. D. Hurst
Regional Forester

cc: Division Chiefs
H McKirdy

WATER QUALITY MONITORING PROGRAM
R-3 USFS

INSTRUCTIONS/SUGGESTIONS

1) All stations set-up for monitoring are to be run a minimum of four (4) times per year as follows:

   Once (1) during high flow period
   Once (1) during medium flow period
   Twice (2), possibly three (3), during low flow

2) Only those determinations starred* need to be analyzed for purposes of the initial monitoring program. It would be desirable to run all twenty (20) determinations at each station once/year (preferably during low flow).

3) The kit that you have been supplied with can be used for several drinking water determinations such as chlorine, flouride, detergents, nitrates, etc. It would be most beneficial to run tests on the Forest drinking water supplies at least once per year. Other meter scales, reagents and glass filters can be obtained for use with this colorimeter. Over 40 tests can be determined.

4) Because of the delicate instrument and consistancy needed in monitoring these waters, it is recommended that only one or two persons do the actual analysis.

5) Collections can be made by the District if so desired; for accuracy, analysis should be run as soon as possible and preferably no later than 72 hours after collection. This is the prime and most desirable feature of the field kit.

6) A copy of the field analysis work sheet should be submitted to the Watershed Division in the Regional Office as soon as possible after the check has been made. You should keep a copy in the forest files also.

7) A Book of Procedures is supplied with each colorimeter field kit.

8) If water Quality Problems exist that need immediate attention, contact the Division for assistance. (McKirdy, Watershed Division)

CHEMICAL-PHYSICAL

R-3 USFS

WATER QUALITY MONITORING
(Field Analysis)

FOREST ______

STORET NUMBER [| | | | |]

Stream/Lake ______

Watershed Planning Unit ______ Unit No. ______

Location ______ T.____ R.____ Sec. ______

Collection Date ______ Y Y M M D D

Analysis Date ______

Collection Time (Military) ______

Sample Number ______

Air Temp., °F ______

Temp. Range (Min.) ______ (Max.) ______

Water Temp., °F ______

Dates of Temp. Range ______ To ______

*1. Alkalinity (PHTH) ______
(M.O.) ______
*2. Carbon Dioxide ______
*3. Chloride ______
*4. Copper # ______ #
*5. Hardness, Calcium ______
Total ______
*6. Iron # ______ #
*7. Manganese # ______ #
*8. Oxygen, Dissolved ______
*9. pH ______
*10. Sulfate ______
*11. Total Dissolved Solids ______
*12. Turbidity (Units) ______
*13. Flow (C.F.S.) ______

14. Chlorine ______
15. Chromate ______
16. Detergents ______
17. Flouride ______
18. Hydrogen Sulfide ______
19. Nitrate ______
20. Phosphate, Ortho ______
Poly ______
21. ______
22. ______
23. ______
24. ______
25. ______
26. ______
27. Weather ______

(Parts Per Million Unless Indicated Otherwise)

WORK SHEET

Use Micrograms/Liter
(PPM x 1000)

Revised 12/69

R-3 Interim Water Quality Guide Supplement

The following water quality determinations should be made, as a minimum, in reference to a particular activity which could have a significant effect on water quality. These measurements are needed on a temporary monitoring basis when planned activities are known. It is desirable to check these waters prior to, during, and after a programmed activity.

Logging Operations

Test for:

1. Turbidity - (include flow measurements in CFS).
2. Dissolved Oxygens (a reduction of D.O. due to oxidation of organic solids could be expected).
3. Total alkality (M.O.) - an increase could be expected from slash burning.
4. pH.
5. Water temperature - a min.-max. thermometer should be placed in the stream and checked from time to time.
6. Sulfates - an increase in sulfates can be expected in the S.W. as a result of runoff water.
7. Total Dissolved Solids.
8. Bottom fauna analysis - when water quality is effected severely a change in species composition is observed. Note any decrease in species and increase in numbers.

Road Construction

Test for:

1. Turbidity (record flow in (FS)
2. Water temperature (use min.-max. thermometer)
3. Dissolved Oxygen
4. pH
5. Sulfate
6. Total Dissolved Solids

Mining Activities

Test for:

Much of this would depend on mineral being mined and process used to extract. The following should be analyzed at all mining activities.

1. Turbidity
2. Water temperature
3. Dissolved Oxygen
4. pH
5. Alkalinity, total (M.O.)
6. Total dissolved solids
7. Iron
8. Manganese
9. Bottom fauna sampling
10. Other (such as Copper, Cyanide, etc. depending on ore and extraction process)

Summer Homes - Recreation Areas - Administrative Sites

1. Chloride
2. Chlorine
3. Chromate
4. Detergents (ABS-LAS)
5. Nitrate
6. D.O.
7. pH
8. Phosphate
9. T.D.S.
10. Turbidity (include flow measurement in CFS)
11. Bottom fauna sampling

ALKALINITY

Like acidity, alkalinity is not a specific polluting substance, but rather a combined effect of several substances and conditions. Alkalinity is caused by the presence of carbonates, bicarbonates, hydroixdes, and to a lesser extent by borates, silicates, phosphates, and organic substances. Alkalinity is related to pH but high alkalinities should not be confused with high pH values. The alkalinities of streams are frequently increased by the addition of municipal sewage and many industrial wastes.

The M.O. (methyl-orange) endpoint measures the total alkalinity whereas the phth (phenolphthalein) endpoint measures the so-called caustic alkalinity.

<u>Domestic</u> - In itself, alkalinity is not considered to be detrimental to humans.

<u>Industrial</u> - Detrimental in many industrial processes, such as those in the production of food and beverages. Desirable in oil field work.
Food and beverages - up to 100 ppm
Other - up to 150 ppm

<u>Irrigation</u> - In conventional chemical analyses, alkalinity is frequently not listed.

<u>Stock & Wildlife</u> - Caustic alkalinity (phth) 50 ppm
Total alkalinity (M.O.) 170 ppm

<u>Fish and Other Aquatic Life</u> - In general the more productive waters which support a diversified aquatic life are those above 100 ppm of total alkalinity.
Range 100-350 ppm.
The addition of lime will increase the alkalinity.

CARBON DIOXIDE

A colorless, odorless, non-combustible gas, constituting about 0.04 percent of normal air, carbon dioxide is highly soluble in water. The source of free carbon dioxide in water is seldom that from the air phase; however, for CO_2 is a product of aerobic or anaerobic decomposition of organic matter.

Domestic Water -	Appears to have no direct physiological effect. High concentration detrimental to water systems as they accelerate the corrosion of iron and steel.
Industrial Waters -	Generally not restricted. Cement and concrete concentration should be below 20 ppm.
Irrigation Waters -	Generally not restricted.
Stock and Wildlife -	Generally not restricted.
Fish and other Aquatics -	20 ppm. God fish fauna less than 5 ppm.

CHLORIDE

Chlorides are found in practically all natural waters. They may impart a salty taste at concentration as low as 100 ppm. Chlorides appear to exert a significant effect on corrosion rate of steel and aluminum.

<u>Domestic Waters</u> - 50 ppm, toxic reaction to most plant.

<u>Irrigation</u> - 100 ppm.

<u>Stock and Wildlife</u> - 1500 ppm.

<u>Fish and Other Aquatics</u> - 170 ppm, much less for good fish fauna.

CHLORINE

An elemental form of a greenish-yellow gas which dissolves readily in water and used extensively as a bactericidal agent in municipal water works.

Domestic Waters - Not restricted in normal concentrations.

Industrial Waters - 2 ppm, depends on product.

Irrigation Waters - 50 ppm.

Stock and Wildlife - 200 ppm.

Fish and Other Aquatics - 1 ppm, trout have been killed after two hours of exposure at 0.3 ppm of free chlorine.

CHROMATE (CHROMIUM)

Chromium compounds may be present in wastes from various industry, or they may be discharged in chromium-treated cooling waters. It is also used as a corrosion inhibitor in cooling systems and in the biological sewage treatment processes and sludge digestion.

Domestic Water - 0.05 ppm.

Irrigation Waters - 1-20 ppm, depending on crop.

Industrial Waters - Information not available, but would depend on product(s).

Stock and Wildlife Water - 5 ppm.

Fish and Other Aquatics - 0.05 ppm.

Coliform Group

1 - Escherichia Coli ("Fecal Coli") is characteristically an inhabitatn of human and animal intestines.

2 - Aerobacter aerogenes and aerobacter cloacae - found in vegetation and in materials used in joints and valves of pumps, and in pipelines. Also commonly found in soil and in waters polluted sometime in the past (I.A.C.)

A - "Esch. Coli" - referred to as "Fecal Coli".

B - I.A.C. Group - referred to as "Nonfecal".

In general terms, the presence of fecal coliform organisms indicates <u>recent</u> and possibly <u>dangerous</u> pollution. The presence of I.A.C. organisms suggests less recent pollution or reveals the existence of defects in water treatment or distribution.

COPPER

Copper salts occur in natural surface waters only in trace amounts, up to about 0.05 ppm, so that their presence is generally the result of pollution.

Domestic Waters -	The limiting factor is taste. 1 ppm.
Industrial Waters -	2-20 ppm, depending on product.
Irrigation Waters -	0.1 ppm, toxic to most plants.
Stock & Wildlife -	Small amounts of copper are beneficial. No information available on numerical amounts.
Fish and Other Aquatics -	0.02 ppm, would be less toxic in hard waters.

CYANIDE

Recent work by research people have demonstrated that "Hydrogen Cyanide" rather than cyanide is the toxic component. When toxicities are expressed in terms of the cyanide ion, it must be realized that most of the cyanide in water is in the form of HCN. This would then make the effect of pH on cyanide toxicity of great importance - the lower the pH, the greater the toxicity. Research (Doudoroff, 1956) found a change in pH from 7.8 to 7.5 increased the toxicity ten times. The toxicity of cyanide is affected by the pH, temperature, dissolved oxygen and mineral concentrations. Problems of cyanide toxicity to fish have been found in the Red River on the Carson National Forest. Cyanides occur in the effluents from various industrial uses such as metal cleaning, electroplating processes and chemical industries.

<u>Domestic Waters</u> (Water Supply)	- 0.01 ppm
<u>Industrial Waters</u>	- Information lacking.
<u>Irrigation Waters</u>	- Information lacking.
<u>Stock and Wildlife</u>	- 100 ppm cows - ducks HCN Information lacking on other sp.
<u>Fish and Other Aquatics</u>	- 0.15 - 0.3 ppm HCN

DETERGENTS (ABS)

Synthetic surface-active agents were developed primarily to overcome the disadvantages of soaps in hard water. Today it is estimated that over 85 percent of the annual soap and detergent sales is that of synthetic detergents. Almost the entire annual production (approximately 4 billion pounds) of synthetic detergents are discharged to a ground or surface water and that ABS, the most common ingredient, is resistent to biological metabolism, account for the rising incidence of surface-active materials as water-quality problems. A recent study in California indicated high concentrations of ABS at a soil depth of 400 feet. A study in Nebraska indicated that after 14 months use, a sewage lagoon system had contaminated ground water with synthetic detergents for a radius of three-fourths mile.

Domestic Waters. 0.5 ppm

Industrial Waters. No information available

Irrigation Waters. No information available

Stock & Wildlife. No numerical values available. Livestock will refuse to drink at high levels.

Fish & Other Aquatics. 3.5 to 8 ppm

DISSOLVED OXYGEN

Inadequate oxygen in surface waters may contribute to an unfavorable environment for fish and other aquatic life and the absence of DO may give rise to odoriferous products of decomposition. The presence of dissolved oxygen in domestic supply systems is seldom considered to be deleterious, however, it does stimulate corrosion. Several factors including species and age of fish, temperature, and concentration with other substances all have a bearing on the requirements and levels of dissolved oxygen.

Domestic Water Supplies. Seldom considered

Industrial Waters Seldom considered. Such uses as power reactors and boiler feed water need as close to o o ppm as possible.

Irrigation. Not considered

Stock & Livestock Waters. Not considered.

Fish and Other Aquatics. Cold Water Species) 6 ppm
Warm Water Species) 4 ppm

FLOURIDES

Domestic Waters. .7 - 1.2 ppm, depends on annual average of maximum daily air temperatures.

Industrial Waters. 1 ppm.

Irrigation Waters. 10 ppm.

Stock & Wildlife Waters. 1 ppm.

Fish and Other Aquatics. 1.5 ppm.

HARDNESS

In natural waters, hardness is chiefly attributable to calcium and magnesium ions. Other ions such as aluminum, manganese, iron, copper, lead, zinc, barium and strontium are also responsible for hardness. In natural waters, hardness is generally correlated with dissolved solids. Natural accumulation of salts from soil and geological formations, direct pollution by industrial wastes and return flows from irrigation may increase hardness.

Detrimental effects of hardness would be such things as excessive soap consumption in homes and laundry, toughening of vegetables cooked in hard water, formation of scale in boilers, hot water heaters, pipes and utensils.

<u>Domestic Water Supplies</u>	-	Good quality should not exceed 270 ppm.
<u>Industrial Waters</u>	-	120 ppm textiles to 7000 in cooling waters.
<u>Irrigation</u>	-	Generally hard waters are superior to soft waters. Usually reference is made to calcium, sodium, sulfates, etc.
<u>Stock & Wildlife Waters</u>	-	No apparent effects.
<u>Fish and Other Aquatics</u>	-	Avoid hardness determinations in dealing with water quality requirements for aquatic life.

HYDROGEN SULFIDE

Normally associated with lakes or other slow moving waters. This is a flammable, poisonous gas with a characteristic odor of rotten eggs and is highly soluable in water. The sources of H2S in water include natural processes of decomposition, sewage and industrial wastes.

Domestic Water Supply - 0.05 ppm (taste)

Industrial Waters - Depending on use. 0.2 baking & confectionary
5.0 boiler feed water & cooling

Irrigation Waters - Information lacking

Stock & Wildlife Waters - Possibly a taste and odor deterent, no other information available.

Fish and Other Aquatic - 0.3 to 1 ppm

IRON

Natural waters become polluted by iron-bearing industrial wastes, by leaching of soluble iron salts from soil and rocks, acid mine drainages and iron-bearing ground water. The effects to fish and aquatics is in the form of soluble iron which may lower the PH of the water to a toxic level, also the gills of fish are very sensitive with the iron hydroxides causing irritation and blocking of the respiratory channels.

Domestic Water Supplies	0.3 ppm
Industrial Waters	0.3 ppm - Textiles - food 1.0-14 ppm _ Cooling waters
Irrigation Waters	Considered minor, could even be considered beneficial in some instances.
Stock and Wildlife	Essential constituent of animal diets, but animals are sensitive to changes in iron concentration. No limits given.
Fish and Other Aquatics	- 1 ppm depending on form and whether in solution or suspension. Some fish affected by as little as 0.2 ppm.

MANGANESE

Manganese metal is not found pure in nature, but its ores are very common and widely distributed. It frequently accompanies iron and in much of the literature are linked together. Manganese in ground water, which is subject to reducing conditions, can be leached from the soil and occur in high concentrations. The manganese metal or its salts are used in many industrial and agricultural operations such as steel alloys, glass and ceramic processes, manufacture of paints and varnishes, in inks and dyes, and in agriculture to enrich manganese - deficient soils.

<u>Domestic Water Supplies</u>	-	(taste) 0.05 ppm
<u>Industrial Waters</u>	-	0.05 to 0.1 ppm (depending on use)
<u>Irrigation Waters</u>	-	0.50 (to 2.0 ppm) depending on plant.
<u>Stock and Wildlife Waters</u>	-	10 ppm
<u>Fish and Aquatics</u>	-	1 ppm

NITRATE

Nitrates are found in waters of enrichment such as an excessive application of fertilizer, leachings from cesspools, natural degradation and indirectly by inorganic industrial wastes. In spite of the many sources, nitrates are generally abundant in natural surface waters. They are an essential fertilizer to all types of plants and are readily used during the photosynthisis process. This is not the case in deep ground waters, and consequently, such waters carry excessive and deleterious concentrations of nitrates.

Domestic Water Supplies.	45 ppm (in excess, potential dangers in using water for infant feeding.
Industrial Waters.	15-30 ppm, depending on use.
Irrigation Waters.	In general, nitrates are desirable
Stock & Wildlife Waters:	Not known
Fish & Other Aquatics.	Most desirable for good fish life. 5.oppm (Needed for plant growth, however, too much would possibly cause an oxygen depletion).

pH

An expression of the hydrogen ion which in itself is a potential pollutant, also is a measure of potential pollution. It is related to the concentration of many other substances, particularly the weakly dissociated acids and basis. Most domestic sewages are neutral or slightly alkaline (pH 7-7.5), with a strong buffering action. pH concentrations of raw water source for domestic water is important in that it affects taste, corrosion efficiency in treatment and industrial applications. High pH favors corrosion control whereas a low pH would acquire a "sour taste."

Domestic Water Supply -	No limits set but most ideal between 6-8.
Industrial Waters -	Depends on use but generally ideal between 6.5-8.5.
Irrigation Waters -	Depends on crops, here in SW the low pH values are most desirable with a pH of 9 or above considered not suitable.
Stock and Wildlife Waters -	No available data, however, for best waterfowl foods between 7.0-9.2. Taste may also have a direct affect on use.
Fish and Other Aquatics -	6.5-8.5

PHENOL

A colorless, crystalline substance with a characteristic odor is used widely as a disinfectant, manufacture of resins, medical and industrial compounds and as a reagent for chemical analyses. Pheolic wastes arise from many sources such as human and animal refuse, oil refineries, chemical plants, gas works, choke ovens, sheep dips and other. Probably the most objectionable thing about phenols are the taste and odor characteristics, however, in extreme concentrations could be toxic.

Domestic Water Supplies -	0.001 ppm.
Industrial Waters -	Depends on use. Undesirable in food and beverage industry. No numerical values obtainable.
Irrigation Waters -	Not considered deleterious, up to 50 ppm.
Stock and Wildlife Waters -	Believed not to be toxic in concentrations as high as 10,000 ppm. Again taste and odor could result in non-use of water.
Fish and Other Aquatics -	0.2 ppm. Primarily taste of fish flesh. Lethal effects approx. 9 ppm.

PHOSPHATES

The major sources of phosphorous entering fresh waters are domestic sewage effluents, including detergents, animal and plant processing wastes, fertilizers and chemical spillage, various industrial effluents and to some extent erosion materials in agricultural runoff. Phosphates in natural waters are seldom found in significant concentrations as they serve as nutrients and are utilized by plants. Excessive amounts of phosphates are normally an indicator of pollution and should be further analized for other constituents such as nitrates, detergents and others. Excessive amounts discharged to streams or lakes may result in an overabundant growth of plant material which could be detrimental to the fishery.

Domestic Water Supplies -	No limit specified. Due to possible physiological effects and taste it is suggested by one source not to exceed 50 ppm and another source 180 ppm.
Industrial Waters -	Depends on use. 4 ppm cooling waters 50 ppm boiling water.
Irrigation Waters -	Little importance; likely to be beneficial.
Stock and Livestock -	Little importance.
Fish and other Aquatics -	May be beneficial by increasing algae and zooplankton.

SULFATE

Sulfates occur naturally in water, particularly in the Southwest, as a result of leachings from gypsum or pyrite bearing strata. Sulfates may also occur as the oxidized state or organic matter, and from industrial wastes such as tanneries, sulfate-pulp mills, textile mills, etc.

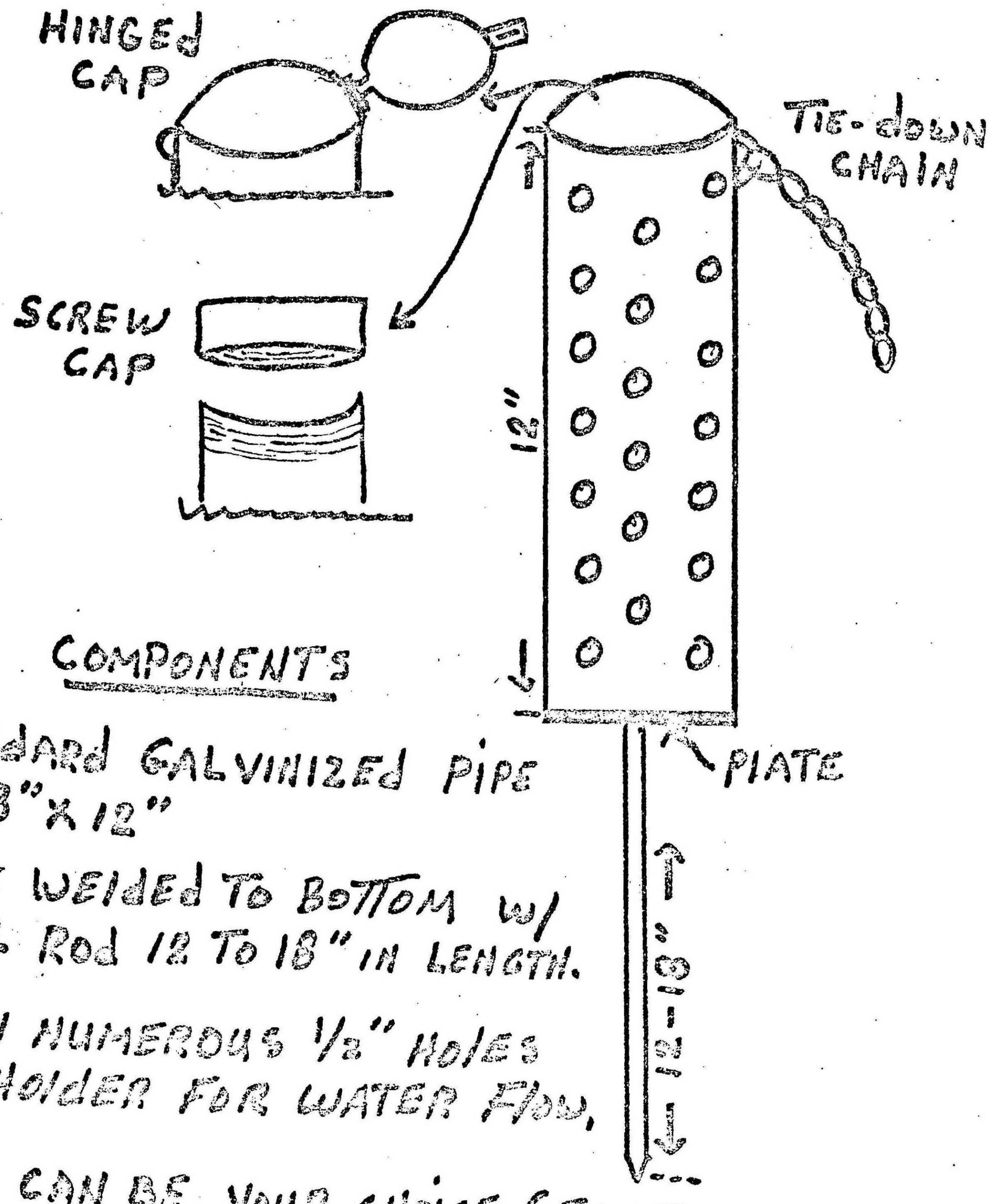
Domestic Water Supplies -	250 ppm
Industrial Waters -	Depends on use. 20-25 ppm (concrete) 100 ppm (textiles) 250 ppm (beverages)
Irrigation Waters -	Best conditions. 200 ppm.
Stock and Wildlife Waters -	500 ppm
Fish and Other Aquatics -	90 ppm.

TEMPERATURE

Temperature changes in water may result from natural climatic conditions, industrial wastes such as certain effluents and cooling waters, and by changes in the environment. The temperature is important and sometimes critical for many uses of water. It affects the palatability, treatment processes, cooling processes and suitability as a habitat for aquatic life. Thermal pollution is becoming a major concern in water quality control. Flocculation and sedimentation rates are increased with temperature rises. The bactericidal effects of disinfectants, such as chlorine, are generally increased with temperature increases. There are optimum or preferred temperatures for fish, also lethal effects due to rapid changes and duration of temperatures.

Domestic Supply Waters -	$50^{o}F$ Satisfactory $59^{o}F$ Objectionable
Industrial Waters -	52 to $120^{o}F$ Depending on use
Irrigation Waters -	Could be important to certain plants such as rice which does best at 59 to $65^{o}F$.
Stock and Wildlife Waters -	No available information.
Fish and Other Aquatics -	Cold water - less than $69^{o}F$, 55 to $65^{o}F$ preferred Warm water - less than $96^{o}F$ 86 to 90 preferred

MIN/MAX. THERMOMETER HOLDER



COMPONENTS

STANDARD GALVINIZED PIPE
3" X 12"

PLATE WELDED TO BOTTOM W/
STEEL ROD 12 TO 18" IN LENGTH.

DRILL NUMEROUS 1/2" HOLES
IN HOLDER FOR WATER FLOW,

CAP CAN BE YOUR CHOICE (FASTEN
SECURELY).

CONSIDER TIE DOWN (ESPECIALLY IN SWIFT WATER)

TOTAL DISSOLVED SOLIDS

A combination of the many salts in solution. The natural salt content of the mountain streams of the region are generally less than 75 ppm. Increases in the dissolved salts is usually an indication of use or to some extent, pollution. The TDS is a good indicator of pollution and as use of our waters become more intensified, the salt content will increase. Fresh water fish can tolerate high concentrations of salt; however, the best waters supporting a good mixed fish fauna are those containing less than 400 ppm.

Domestic Water Supplies -	500 ppm.
Industrial Waters -	150-35,000 ppm, depending on use.
Irrigation Waters -	700 ppm.
Stock and Wildlife Waters -	Less than 10,000 ppm.
Fish and Other Aquatics -	400-2000 ppm.

TURBIDITY

The turbidity of water is the disturbance of cleanness due to suspended matter such as organic detritus, mineral substances, silt, sawdust, various effluents and other. The measurement is based on the extent to which the intensity of light passes through a given water sample and is measured in a standard unit. (Jackson Turbidity Unit)

Domestic Water Supplies -	5 units.
Industrial Waters -	0-100 units depending on use.
Irrigation Waters -	Information not available.
Stock and Wildlife Waters -	Not known.
Fish and Other Aquatics -	100 units for best productivity.

A good indicator as to intensity and duration of sediment to a stream in regards to road building, logging, grazing and other watershed uses.

Bottom Fauna

Bottom conditions (substrate), water quality, depth, water temperature and water velocity all have an influence on aquatic insect populations. The method of sampling found in this guide and being used in the water quality monitoring program in the Region is not intended to meet the statistical (research) requirements. It is intended to give a general macrofaunal sampling which can demonstrate overall levels of abundance from <u>season</u> to <u>season</u> and year to year. It is very useful as an indication of water quality (pollution). Generally, the more groups of insects found is an indicator of the better water quality, whereas, fewer groups regardless of numbers, would indicate a much poorer water quality.

The importance of the biological (aquatic insect) determinations are primarily associated with the water quality during the time lapse between regular periodic sampling of the stations. As an example, let's say that a pollutant (slug) moved downstream over our sampling station at a time between regular sampling periods. In all probability this slug would destroy a part of the most intolerable species which in most cases are the better or only insects utilized by fish. Our sampling of the stations during the next period would provide fewer groups and an indication of a water quality change or seasonal variation.

RESPONSES OF AQUATIC ORGANISMS TO ORGANIC POLLUTION

I INTRODUCTION

A Since the animals and plants in a stream are exposed to all of the pollution which flows in that stream they are of necessity affected by it.

B It is therefore our objective to examine what these effects are and in reverse to infer what water conditions may have caused them.

C Some types and quantities of pollutants kill everything. The complete absence of life in a stream would thus indicate a presence of a highly toxic condition in that stream within the relatively recent past.

D Responses to sewage type pollution are best understood and are the main consideration here.

E There is no single organism or group of organisms which can be referred to as "the" indicator of pollution.

II Organisms attached to or crawling on the bottom are known as benthos. In contrast to the plankton the benthos stay in one place and are exposed to whatever succession of materials is brought down by the current. They are not representative of the "average" mass or "slug" of water but are rather indicative of the "worst" mass that has recently passed.

A Microscopic benthic organisms such as protozoa have been relatively little studied but seem to follow similar principles of distribution to the larger forms.

B The non-microscopic benthos or macrobenthos are most readily observed and are very useful. They include the insect larvae, worms, "bugs" and other myriads of creatures one sees in a flowing stream.

1 An understanding of certain basic laws governing the distribution of organisms will aid greatly in interpreting their presence or absence from a particular station in a stream. The following principles should be borne in mind.

a Particular organisms tend to be present in all suitable habitats.

b Any given habitat tends to harbor all suitable species which might be expected to occur therein.

c The law of the minimum (or maximum) states that "organisms are limited in their distribution by minimum or maximum values of certain critical factors" such as DO or temperature.

2 The significance of these principles is that if an organism might be expected to be present in a given type of station but is not found, the question can be raised - why is it not here? Has some critical value such as DO dropped too low or has the temperature gone too high? On the other hand the presence of a given species is mute evidence that tolerable standards for this species have not been exceeded.

3 A knowledge of the length of life history of the various species is important. An abundance of a species which requires only 2 weeks to grow, coupled with the absence of expected species which might require several months to mature might indicate, for example, that the stream was wiped clean by a slug of pollution 3 or 4 weeks before sampling.

4 Seasons and temperature affect the plants and animals very greatly. Some species flourish most abundantly in the winter, other species in the summer season. Therefore the collector would not expect all species to be equally abundant at all times of the year.

5 The geographic location of the stream is also significant. One would not expect the same combinations of species in a stream in New England, Florida and Ohio.

C In summary of the foregoing concepts it might be stated that the more complete ones' knowledge of the life to be found in in a stream the better interpretation could be made of its pollutional significance. On the other hand certain basic ideas are outlined below which can be observed by anyone familiar with field observations.

III Important items to observe in interpreting the pollutional significance of stream organisms are:

A Numbers of species present; they tend to decrease with pollution.

B Numbers of individuals of each species tends to increase with pollution.

C Ratios between types of organisms are disturbed by pollution.

1 Clean water species intolerant of pollution tend to become scarce and unhealthy.

2 Organisms with air breathing devices or habits tend to increase in numbers.

3 Scavengers become dominant.

D The importance of observations on any single species is very slight.

IV The existence of a general sequence of conditions for organic pollution has been known for a long time. The chemical and biological characteriestic of the successive stages or zones have been more thoroughly investigated recently.

A The Clean Water Zone

1 General features

a DO high

b BOD low

c Turbidity low

d Organic content low

e Bacterial count low

f Numbers of species high

g Numbers of organisms of each species moderate or low

h Bottom free of sludge deposits

2 Characteristic fauna includes wide variety of forms such as:

a Caddis fly larvae (Trichoptera)

b Mayfly larvae (Ephemeroptera)

c Stonefly larvae (Plecoptera)

d Damselfly larvae (Zygoptera)

e Beetles (Coleoptera)

f Clams (Pelecypoda)

g Fish such as:

Minnows, Notropid type
Darters (Etheostomidae)
Millers thumbs (Cottidae)
Many sunfishes and basses (Centrarchidae)
Sauger, yellow perch, etc. (Percidae)
Others

B Zone of Degeneration, or Recent Pollution, Very Variable

1 General features

a DO variable, 2 ppm to saturation

b BOD high

c Turbidity high

d Organic content high

e Bacterial count variable to high

f Number of species declining from clean water zone

g Number of organisms per species tends to increase

h Other: Slime appearing on bottom

2 Characteristic fauna

a Midge larvae (Chironomidae or Tendipedidae) becoming more abundant

b Back swimmers (Corixidae) and water boatmen (Notonectidae) often present

c Sludge worms (Tubificidae) common

d Dragonflies (Anisoptera) often present have unique tail breathing strainer

e Fish types

Fathead minnows (Pimephales promelas)
White sucker (Catostomus commersonnii)
Bowfin (Amia calva)
Carp (Cyprinus carpio)

C Septic Zone, or Zone of Putrifaction

1 General features

a DO little or none during warm weather

b BOD high but decreasing

c Turbidity high, dark, odoriferous

d Organic content high but decreasing

e Bacterial count high

f Number of species very few

g Number of organisms: may be extremely high or none at all

h Other: Slime blanket and sludge deposits usually present, oily appearance on surface, rising gas bubbles

2 Characteristic fauna

a Mosquito larvae

b Rat-tailed maggots

c Sludge worms (Tubificidae)

d Air breathing snails (Physa)

e Fish types: None

D Zone of Recovery, May be Subdivided. Often Abnormally Productive

1 General features

a DO 2 ppm to saturation

b BOD dropping

c Turbidity dropping, less color and odor

d Organic content dropping

e Bacterial count dropping

f Numbers of species increasing

g Numbers of organisms per species decreasing, (with the increase in competition)

h Other: less slime and sludge

2 Characteristic fauna

a Midge larvae (Chironomids)

b Black fly larvae (Simulium)

c Giant Water bugs (Belostoma spp.)

d Clams (Unio)

e Fish types

Green sunfish (Lepomus cyanellus)
Common sucker (Catostomus commersonnii)

Flathead catfish (Pilodictis olivaris)
Stoneroller minnow (Campostoma anomalum)
Buffalo (Megastomatobus cyprinella)

E Clean Water (Downstream)

1 General features: similar to upstream clean water except that it is now a larger stream.

2 Characteristic fauna: similar to upstream clean water fauna except that species include those indigenous to larger stream.

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This outline was prepared by H. W. Jackson, Chief Biologist, FWPCA Training Activities, SEC.

Biological

R-3 USFS FOREST____________________

WATER QUALITY MONITORING (Field Analysis)

Stream/Lake____

Watershed Planning Unit____________________Unit No.______________

Location____

Collection Date__________________Temp., (water)__________________°F

Width of Stream (sampling stat.)_____ft. Depth of Stream (sampling stat._____in.

Substrate: Mucky__________Sand__________Gravel__________

Rock__________Boulder__________Rubble__________

Shade (percent)__________________Time__________________AM PM

SQUARE FOOT BOTTOM SAMPLE (2 samples per station)

Combine both samples as one bottom fauna measurement per station. Count only the larger organisms (identified with naked eye) and record number of each group.

1. TRICHOPTERA (caddisfly)__________
2. EPHEMEROPTERA (mayfly)__________
3. DIPTERA (trueflies):
   Tipulidae (cranefly)__________
   Culicidae (mosquitoes)__________
   Simulidae (blackflies)__________
   Tendipedidae (midges)__________
   Other__________
4. PLECOPTERA (stonefly)__________
5. HEMIPTERA (bugs):
   Hydrometridae (treaders)__________
   Gerridae (striders)__________
   Notonectidae (back swimmers__________
   Belostomatidae (giant water bug__________
   Corixidae (boatman)__________
6. ODONATA
   Anisoptera (dragonfly)__________
   Zygoptera (damselfly)__________
7. OLIGOCHAETA (aquatic earthworm)__________
8. GASTROPODA (snails)__________
9. PELECYPODA (clams)__________
10. DECAPODA (crayfish)__________
11. COLEOPTERA (beetles):
   Dytiscidae (pred. diving beetles)__________
   Hydrophilidae (water scavengers)__________
   Gyrinidae (whirligigs)__________
   Other__________

REMARKS:

BY:__________________

WORK SHEET

PROCEDURE USED FOR THE SEPARATION OF AQUATIC INSECTS FROM OTHER DEBRIS USING THE FLOTATION TECHNIQUE

The equipment and procedures described below were used in the separation of aquatic organisms from other debris collected in bottom samples for the water quality monitoring program. The equipment (sieve size) and procedures can be modified as necessary to meet varying sample conditions.

Equipment

1. Dissecting pan, white enamel 12" x 17"
2. Sieves, U.S. standard sieve series
   a. #200 (74 micron, 0.0029 inches)
   b. #30 (595 micron, 0.234 inches)
3. Hydrometer, capable of reading a specific gravity of 1.12 directly.
4. Wide mouth jar with cap
5. Fine mesh scoop (approximately tablespoon in size, mesh depending on size of majority of aquatic insects).
6. Dissecting kit.

Procedures

1. Prepare a sugar solution in the wide mouth jar with a specific gravity of 1.12.

   CAUTION - Be sure solution is as close to a specific gravity as possible. Solutions with specific gravities greatly different from 1.12 will cause excess amounts of organic debris to float.

   This solution can be prepared using approximately 2.5 pounds of granulated sugar per gallon of water. If the solution is capped and stored in a cool place, it is reusable for several months.

2. Place the bottom sample debris in the #30 U.S. standard sieve. Wash the sample with clear water to remove the formaldehyde preservative.

3. Turn the sieve with the washed sample upside down in the dissecting pan and flush the debris from the screen using the prepared sugar solution. After removing the sieve, the debris should be evenly distributed over the bottom of the pan.

4. Using the spoon-size fine mesh scoop, the majority of the organisms can be removed from the surface and placed in a petri dish for counting. The debris should be stirred several times to allow organisms entangled in the debris to float to the surface. The few remaining organisms can be individually removed with tweezers.

   CAUTION - Be sure to examine the bottom of the pan for insects in sand cases, molluscs and other organisms to heavy to float.

5. Using the #200 U.S. standard sieve, the sugar solution is poured back into the wide mouth jar for reuse and the remaining debris discarded.

Comments

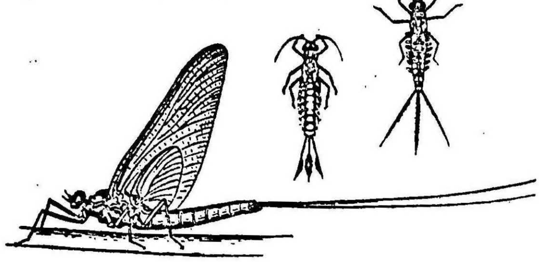
1. Samples containing large amounts of algae and other organic matter should be stirred until there are no more insects that appear on the surface. This organic debris should also be examined for insects that will cling to it.

2. Samples that have large amounts of leaves or other large pieces of organic matter can be washed and removed when the sample is first placed in the #30 sieve.

3. There is ample time (up to 1-1½ hours) to remove the insects, however, after longer periods of time, due to changes in the specific gravity of the organisms, some will sink.

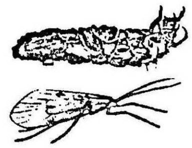
4. The fine mesh scoop can be of any design depending on the nature of organisms. One that worked very well was an old tablespoon drilled with several small (#60 bit) holes. Any scoop that allows the solution to pass through it without disturbing the position of the insect on the surface would be satisfactory.

EPHEMEROPTERA



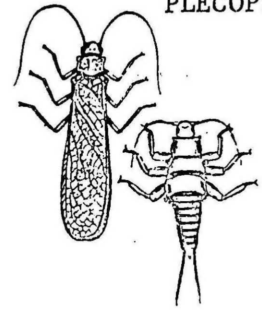
Mayfly and Larva

TRICHOPTERA



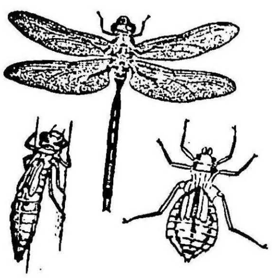
Caddis-Worm in its case and the Caddis-Fly

PLECOPTERA



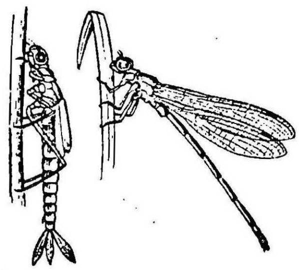
Stone Fly and Larva

ODONATA



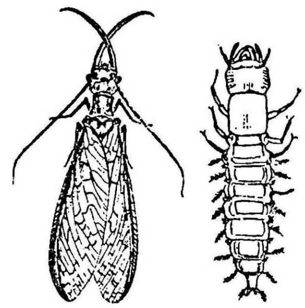
Dragon Fly and Larva

ODONATA



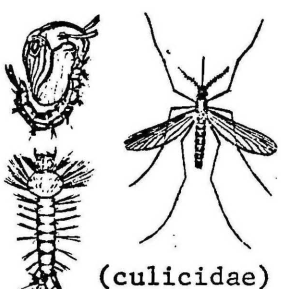
Damsel Fly and Larva

MEGALOPTERA



Dobson Fly and Larva

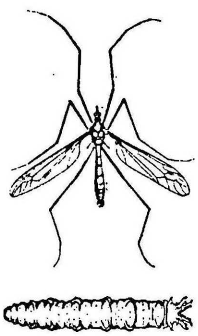
DIPTERA



(culicidae)

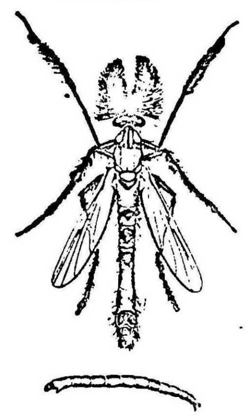
Mosquito and its Larva and pupa

DIPTERA



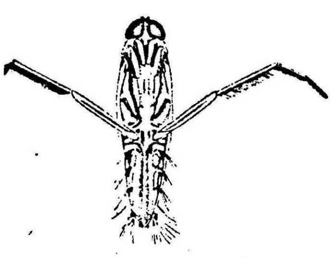
Crane Fly and Larva
(tipulidae)

DIPTERA



Midge and Larva

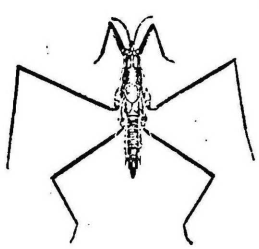
HEMIPTERA



Back-Swimmer

(notonectidae)

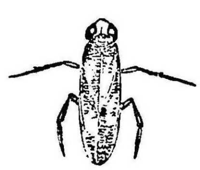
HEMIPTERA



Water Strider

(gerridae)

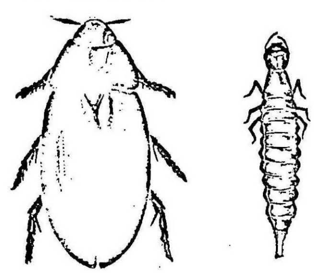
HEMIPTERA



Water Boatman

(corixidae)

COLEOPTERA



Water Scavenger Beetle and Larva

(hydrophilidae)

Fig. 53—Miscellaneous Invertebrates

1. A hydrachnid or water mite
2. A water spider
3. A gasterotrich, Chaetonotus
4. A coelenterate, Hydra
5. A tardigrade, Macrobiotus
6. A bryozoan, Plumatella
7. A bristle worm, Nais
8. A sewage worm, Tubifex
9. A leech, Clepsine
10. A flat worm, Planaria
11. A colonial rotifer, Conochilus
12. A nematode worm
13. A fresh-water sponge
14. Gommules and spicules from the same

INVERTEBRATES

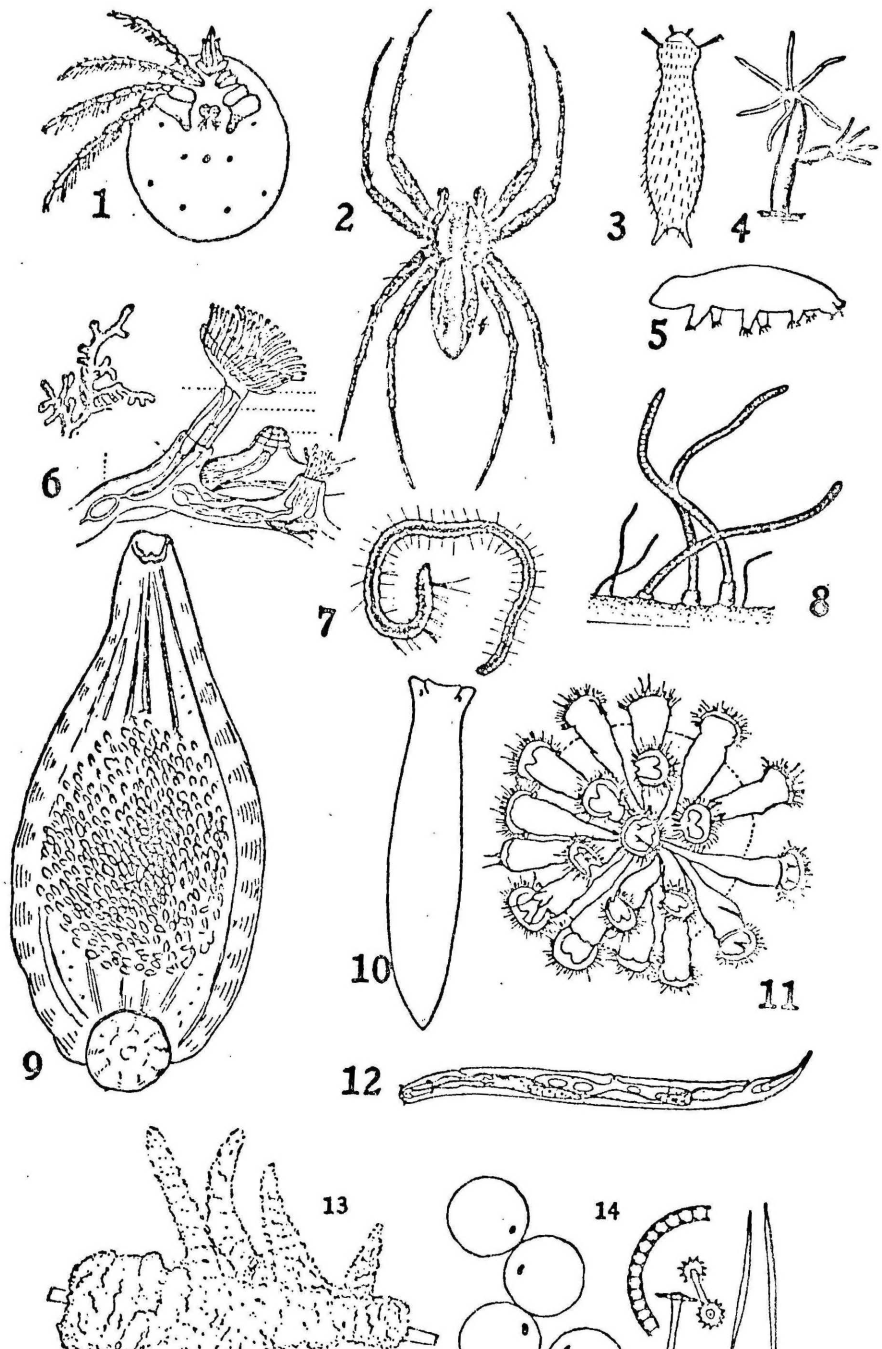


FIG. 53

Fig. 54—Miscellaneous Fly Larvae

1.	Anopheles	17.	Ceratopogon
2, 3.	Culex	18.	Chironomus
4.	Simulium	19.	Corethra
5–8.	Sepedon	20.	Bibiocephala
9.	Tetanocera	21.	Tabanus
10.	Chironomus	22.	Sarcophaga
11.	Simulium	23.	Atherix
12.	Tanytarsus	24.	Stratiomyia
13, 14.	Dixa	25.	Odontomyia
15, 16.	Psychoda	26.	Euparyphus

FLY LARVAE

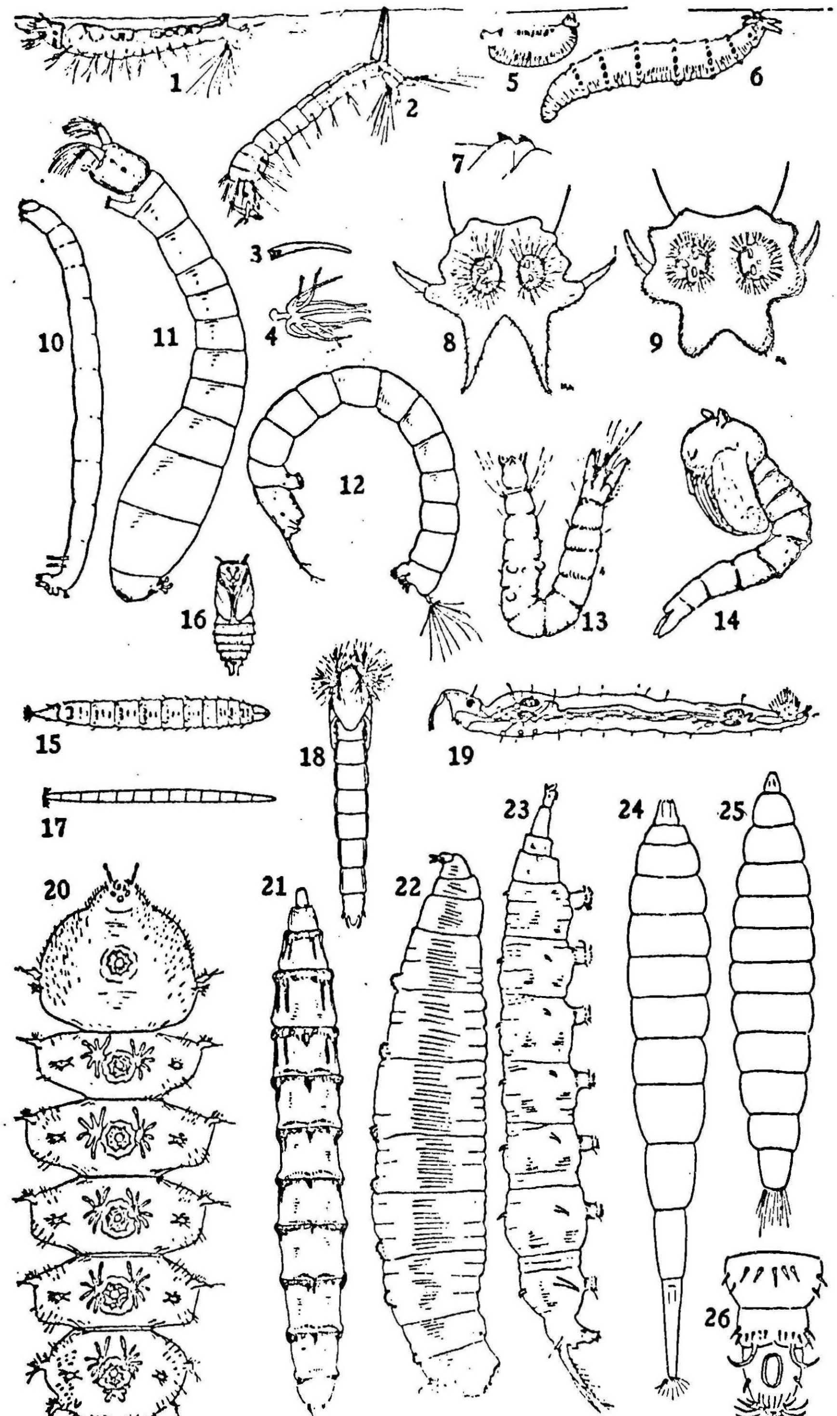


FIG. 54

Fig. 55—Miscellaneous Insects

1. Gyrinidae	9. Sialis
2. Hydrophilidae	10. Sisyra
3. Dytiscidae	11. Elophila
4. Haliplidae	12. Nymphula
5. Parnidae or Elmidae	13. Collembola
6. Peltodytes	14. Philopotamus
7. Haliplus	15. Hydropsyche
8. Chauliodes	16. Halesus

Numbers 1 to 5 represent families of adult beetles

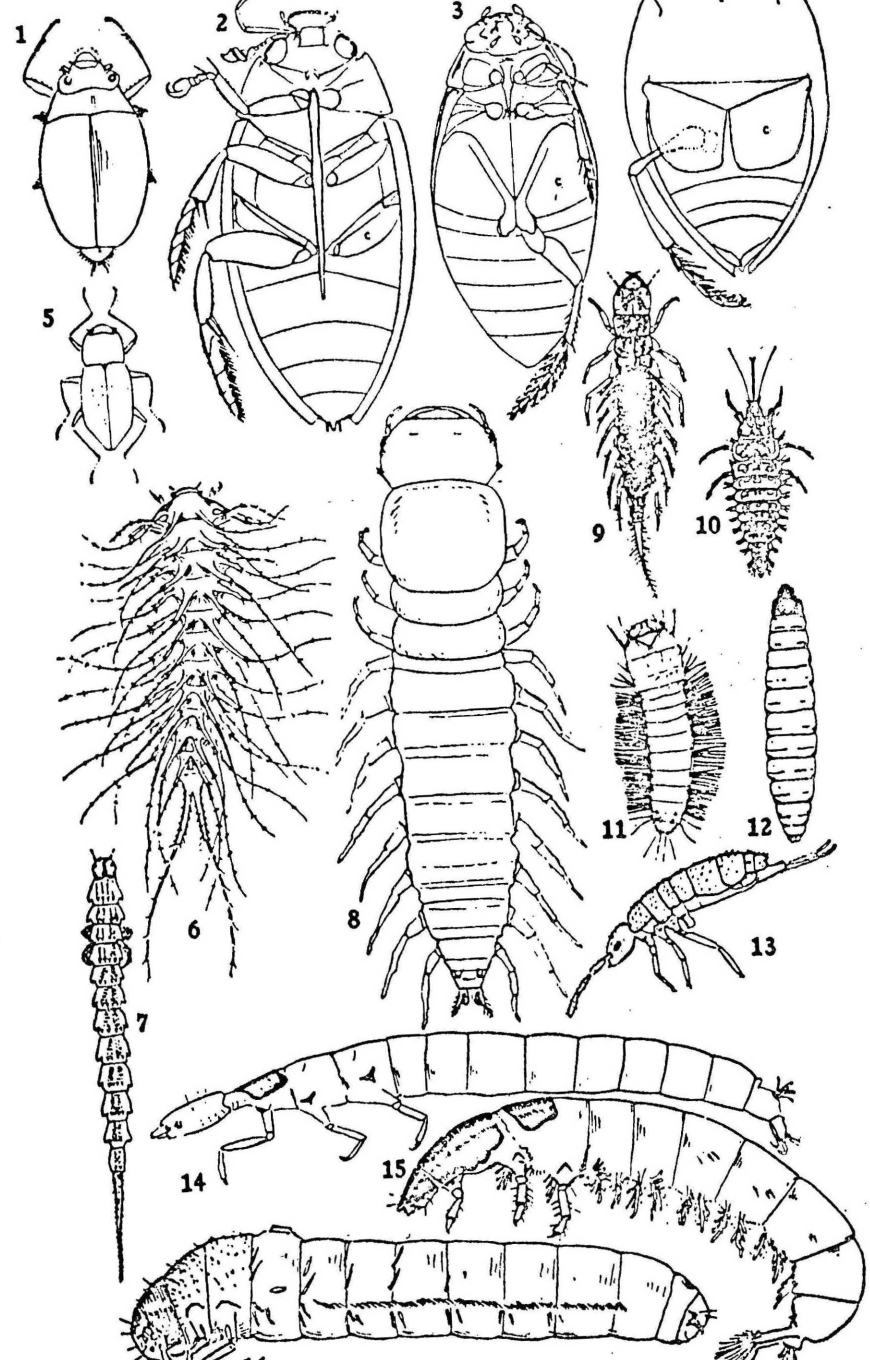


FIG. 55

Fig. 56—Miscellaneous Molluscs

1. Limnea	10. Bythinia
2. Planorbis	11. Amnicola
3. Physa	12. Paludestrina
4. Pleurocera	13. Pisidium
5. Ancylus	14. Musculium
6. Goniobasis	15. Sphaerium
7. Vivipara	16. Margaritana
8. Campeloma	17. Unio
9. Valvata	18. Anodonta

Numbers 4 and 6 show the operculum in detail beside the shell; 9, 10, and 11 show it in the aperture

Molluscs

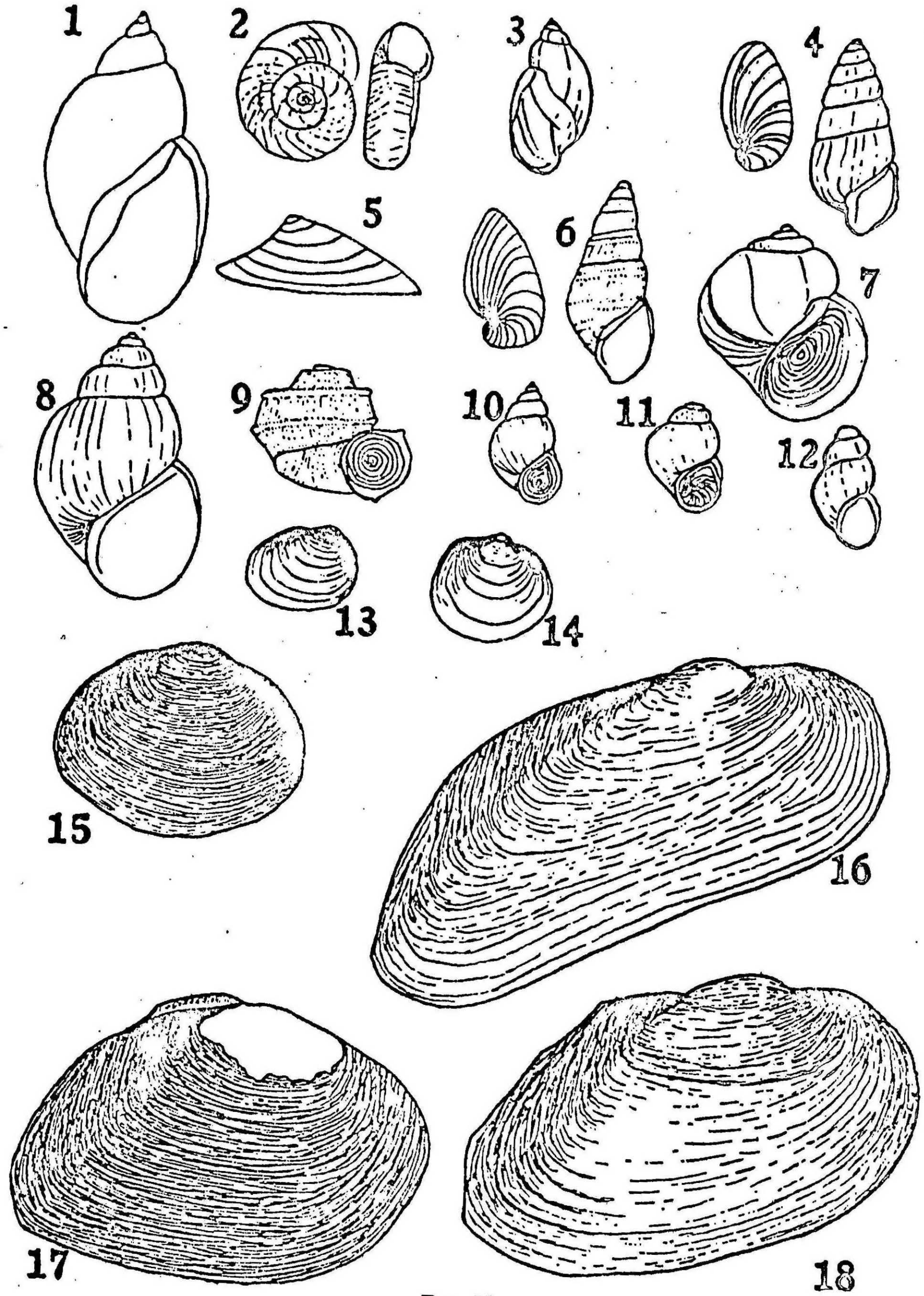


Fig. 56

Fig. 57—Aquatic Insects

1. Odonata, suborder Zygoptera
2. Ephemeroptera, genus Chirotenetes
3. Ephemeroptera, genus Epeorus
4. Odonata, suborder Anisoptera, genus Libellula
5. Ephemeroptera, genus Baetis
6. Diptera, genus Chaoborus
7. Ephemeroptera, genus Hexagenia
8. Plecoptera, genus Perla
9. Coleoptera, genus Dytiscus
10. Neuroptera, genus Cauliodes
11. Trichoptera, genus Philopotamus
12. Diptera, genus Chironomus
13. Diptera, genus Tabanus
14. Diptera, genus Stratiomyia
15. Trichoptera case, genus Brachycentrus
16. Trichoptera case, genus Helicopsyche
17. Trichoptera case, genus Phryganea
18. Trichoptera case, genus Hesperophylax
19. Trichoptera case, genus Hydropsyche
20. Trichoptera case, genus Glossosoma
21. Trichoptera case, genus Molanna
22. Trichoptera case, genus Limnophilus
23. Trichoptera case, genus Astenophylax

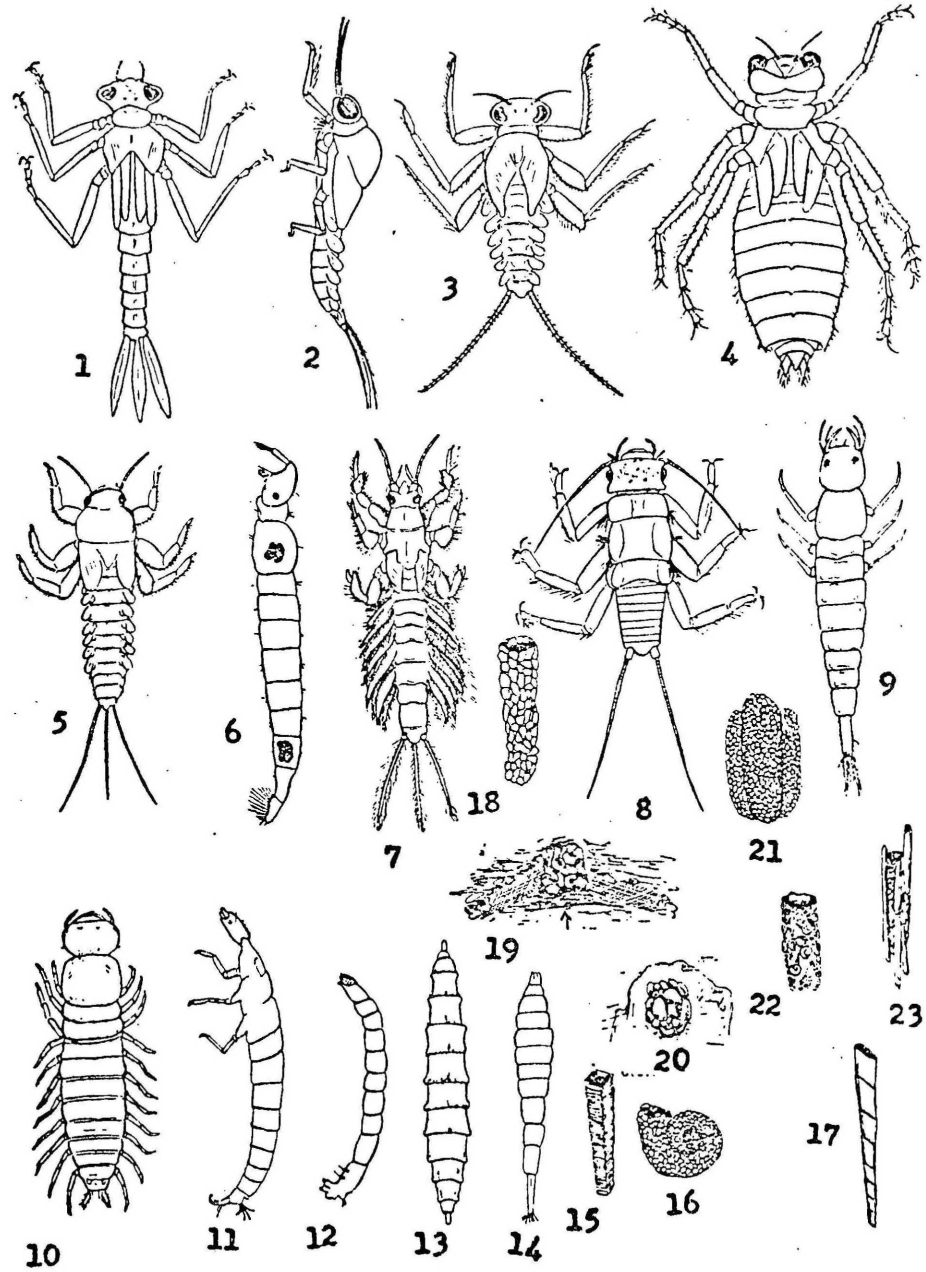


FIG. 57

NAME	DRAGON-FLY	DAMSEL-FLY	MAY-FLY	STONE-FLY
DESCRIPTION	Adults, 4-winged; wings spread at rest; large eyes; relatively slender abdomen; medium-sized legs; most active fliers; favor sunlight. Nymphs, aquatic, with conspicuously hinged lower jaws; some burrow (*Gomphus*); some sprawl (*Libellula*), some climb on water plants (Aeschinnae).	Adults, slender-bodied with netted wings that fold along back when at rest. Heads and eyes, large. Males, frequently more brilliantly colored. Incomplete change. Nymph, aquatic, with 3, plate-like, gill "tails", and a sideways movement of body when in motion.	Adults, thin, delicate wings held over back in rest. Usually with 3, but sometimes 2, long, delicate "tails" and with front pair of legs held conspicuously forward. Incomplete change. Nymphs, aquatic, with 2 or 3 "tails" and gills from side of forepart of abdomen.	Four-winged insects with chewing mouthparts, sometimes not functioning in adults. Incomplete change with the nymphs aquatic; with gills most commonly just behind base of legs in pads and with two "tails". Adults able to fly reasonably well.
WHERE FOUND	Darners fly high; skimmers, lower; 10-spot (figured) at height of 15 feet; amber-wing at 6 feet; argias at 2 feet.	Adults relatively slow flying. Nymphs in ponds or streams but probably most common in quiet water.	Adults in great flocks along fresh-water rivers, lakes and ponds. Nymphs under water.	Adults on land or flying. Nymphs in well-aerated water, usually where it flows.
RANGE	Two American families, the Aeschnidae and the Libellulidae; the former including conspicuous *Gomphus*, *Anax* and *Cordulegaster*; the latter, *Libellula* and others.	Two American families, the narrow, or stalk winged Coenagrionidae, and the generally more beautiful and brilliantly-colored Agrionidae.	Some hundred species known from the United States, although this probably does not include all to be found in the area.	Four American families in the order—the Perlidae with 14 genera; the Nemouridae, with 9; the Capniidae, with 3, and the Pteronarcidae, with 1.
CLASSIFICATION AND LIFE HISTORY	Class Hexapoda. Order Odonata. Sub-order Anisoptera. Males have single appendage at end of abdomen; may hold female by neck. Females may drop eggs in water, or insert them in mud or plant tissue. Incubation usually long, though sometimes about 2 weeks. One brood a year beginning in June. Adults gone by August. Incomplete metamorphosis.	Class Hexapoda. Order Odonata. Sub-order Zygoptera. Males hold necks of females with claspers. Male sex organs near front of body. Females may lay 200 to 300 ovate eggs, 1/25 inch long, by inserting in plants in water; hatch in 3 weeks to several months, and in 10 to 14 stages spend 225 to 624 days.	Class Hexapoda. Order Ephemerida. Family Ephemeridae. Adults live but a day or two, mating in flight. Females drop eggs or place them under water; 500 to 1000 per female; hatch and develop through immature stages in 6 weeks in some species. Others require longer. Molt in adult stage, unlike other insects.	Class Hexapoda. Order Plecoptera. Family Perlidae. Mate out of water. Females drop eggs in masses in water; 200-800 eggs hatching into nymphs, which cling to stones under water and mature in 1, or more—probably 2 or 3—years, then leave water; transform into adults from some elevated point.
BEHAVIOR	Feed solely on animal matter as adults and as nymphs, the different species confining activities to particular regions, but representatives being found in most places in air and water. Perfectly harmless at all times. Often highly inquisitive, investigating a great variety of possible sources of food supply. May roost in considerable numbers at night.	Food of nymphs, probably any aquatic animal life that may be captured; of adults, insects that may be captured in flight even though flight is poor. Protection, largely that of remaining hidden, or because of color like that of the environment. Can hardly be thought of as great defenders of selves.	Food of adults normally nothing, since mouth parts are not developed. Immature forms feed almost entirely on submerged aquatic plants, oozes and slimes of the bottoms of waterways. Little protection outside great numbers and inaccessibility of place where growth takes place. Some burrow in mud.	Food of nymphs small forms of animal life captured while prowling over or under submerged stones in a stream. Adults may eat nothing, but die soon after eggs have been deposited. Protection against current by stream-lined form; from animal enemies by position in current and by ability to hide.
REACTIONS TO HEAT AND LIGHT	Essentially lovers of bright sunlight and warm weather, though the species vary in this respect. Are commonly parasitised at different stages, particularly as eggs, by wasps.	Essentially summer insects, the winter being spent in the nymphal stages. Adults favor sunny days for activities, and most do not leave waterways often.	Great swarms may leave water at same time, probably definitely controlled by light condition; usually transform about middle of July.	Adults attracted by lights. One, *Capnia pygmaea*, a small, dark snow-fly, common on snow in early spring in East, climbs posts and walls to mate.
USE TO MAN AND PLACE IN NATURE	Essentially useful as destroyers of insects such as mosquitoes and gnats that may annoy man, but may prey also on useful insect species. Possibly the most beautiful and graceful of all insects and surely among the more interesting.	May be thought of as food for fish and as scavengers of waterways, although food is essentially living animal matter. Make interesting and sometimes beautiful insects to watch along waterways.	Unquestioned value as basic food for many valuable fishes. May seem to be pests when adults are numerous but eat nothing in that stage. Read Franklin's "To an Ephemera" in his *Autobiography*.	In general useful food for fishes and scavengers of waterways, but a Western species, *Taeniopteryx pacifica*, a serious pest of fruit tree buds in adult stage. Adults make excellent trout bait in season.

NAME	FISH-FLY, DOBSON HELLGRAMMITE	CADDIS-FLIES	CRANE-FLY	MOSQUITO
DESCRIPTION	Adults, wing-spread, more than 5 inches. Males with long, slender, crossed jaws like two hooks. Females with shorter, stouter jaws. Larvae aquatic, breathing through gill-tufts at bases of abdomen segments.	Adults, with four wings densely covered with long fine hairs and held at rest like a roof over the back. Antennae, long, active and usually forward-pointing. Mouth parts of adults not developed. Hind wings, shorter but broader than the fore-wings.	Adults, long-legged, sometimes 2 inches long, with 2 wings and a V-shaped suture between wings. Larvae, usually grayish-white, with or without appendages at one end, an inch or more long and about 1/8 as thick. Pupae, slender, mummy-like and commonly in gravel.	Small, well-known flies, the males with feathery antennae. Wing-margins, fringed; beaks, stout. In *Culex*, resting position with body horizontal; in *Anopheles*, the malarial mosquito, body is held at an angle. Larvae aquatic as are the pupae.
WHERE FOUND	Adults flying near waterways or about lights. Larvae, under stones in moving water.	Adults fly about in air or perch on supports, more commonly near water.	Adults in air or among damp vegetation. Larvae on land, under wet soil or in water. Pupae, commonly in gravel.	Adults in air. *Culex* larvae hang from water surface at an angle; *Anopheles* lie along under surface.
RANGE	(The Family Sialidae has 2 genera of alder flies and several fish-flies, 6 being found in United States and Canada.)	Some 13 families of caddis-flies in North America, the larvae being conspicuously different by the houses they build.	The superfamily Tipuloidea includes in America the Tanyderidae, the Ptychopteridae, the Anisopidae and the Tipulidae with 3000 known species; 500 American.	American *Anopheles*, 9 species, 4 being malaria carriers. Many house mosquitoes of genus *Culex*. Some of the subfamily Corethrinae are not blood suckers. Many tropical species.
CLASSIFICATION AND LIFE HISTORY	Class Hexapoda. Order Neuroptera. Family Sialidae. Subfamily Corydalinae. Mate outside water. Eggs laid in white, blotchy masses, sometimes 1 inch across, on objects over water, about 2000 to a mass. Hatch into larvae that enter water to develop for about 35 months. Then leave water, to pupate for a month in a cell under cover.	Class Hexapoda. Order Trichoptera. One family is the Limnophilidae represented by the genus *Limnophilus* whose larvae build log-cabin-like houses of vegetable material. May be larvae for 11 months, from June to May, then make a different case, sometimes of shells in which pupae may be formed for about 3 weeks before adult stage.	Class Hexapoda. Order Diptera. Family Tipulidae. One species lays about 1000 eggs that hatch in about a week into "black worms", or "leatherbacks", and develop eventually into pupae that live about a week before transforming to adults. Larvae vary greatly in food and habitat.	Class Hexapoda. Order Diptera. Family Culicidae. *Culex* eggs, in rafts; *Anopheles* eggs, laid singly. About 300 *Culex* eggs per female laid in water; hatch in 1 to 7 days into larval wigglers that live in water 6 to 21 days coming to surface to breathe, and transforming to active pupae, which, in 1 to 6 days, become adults.
BEHAVIOR	Food of larvae almost exclusively aquatic animals caught and held by strong jaws that are able to inflict painful bites on humans. Hold on tenaciously. Protection, largely by position under cover under water. Since the larvae are choice fish food they have many enemies.	Food of adults, nothing; of larvae, a great variety of plant and animal materials, some caught by prowling, some by nets stretched in moving water. Protection largely by means of protective houses, some of which are strong. Houses in moving water commonly of stones; in still water, of easily-moved plant materials.	Food of some adults, flower nectar; of others, nothing. Food of larvae varies, some eating animal matter; others acting as scavengers, and still others are plant eaters. Protection of adults by escape and of larvae by hiding. No aggressive protection of individuals.	Females of many species blood suckers, but males not so. Larvae live on minute organisms in the water and are preyed upon by many aquatic animals such as birds, newts, fishes, water beetles and so on, all of which are useful in this connection. Must come to surface to breathe and so an oil film on water suffocates them since they cannot reach the air.
REACTION TO HEAT AND LIGHT	Adults definitely attracted to lights near streams, and since such insects frighten many people they may be killed unnecessarily.	Adults are attracted to the lights. Larvae sensitive to touch and to light, and able to secrete a unique waterproof silk.	Many adults attracted to light. Many form clouds of dancing individuals at definite times of the day. Larvae of some nocturnal.	Most species active at definite times of the day and sensitive to light, temperature and humidity. Particular mosquito species carry diseases to particular animals.
USE TO MAN AND PLACE IN NATURE	Serve as a check on multiplication of some aquatic animals but help man, particularly as an excellent bait for bass and other game fish.	Valuable food for fishes and interesting aquarium pets. The adults often occur in great flocks whose hairs freed into the wind have been known to cause one kind of hay-fever with some persons.	Make good food for fishes, and larvae make excellent bait. Some larvae destroy meadow plants and injure pastures seriously; can be controlled by poison mash of 1 pound Paris green to 25 pounds of bran with water.	A serious pest in most places. Different species known to carry malaria, yellow fever (below the frost belt), dengue, filariasis and other diseases, and to make regions uninhabitable by man.

MIDGE	BLACK FLY	DIVING BEETLE	WATER-SCAVENGER BEETLES	WHIRLIGIG BEETLES WRITE-MY-NAMES APPLE-SEEDS
Adults, like small mosquitoes but more delicate in abdomen, legs and antennae. Antennae of males, feather-like; of females, only sparsely so. Larvae mostly aquatic; some red—known as blood worms—may remain hidden in a case made of silk and oozes.	Adults, small, short, stout-bodied, humped-backed and short-legged. Males, with eyes continuous; females, with eyes separated widely. Many, black, with broad, iridescent naked wings. Larvae, like worms with a sucker disc at tail end and a fringe at head.	Adults with hard forewings. Usually black and brown. When under water show a bubble at tail end. Hind legs modified for swimming. Females of some species with forewings furrowed. Males of some with discs on forelegs. Larvae aquatic, slender, with large jaws, active and voracious.	Usually black beetles, elliptic, more or less flat beneath and convex above; when in water, show under surface silvery with a film of air. Larvae, stouter than those of Dytiscidae the foreparts being more slender and the jaws less conspicuous.	Relatively flat, oval, blue-black, or black, and brown beetles with forward reaching fore-legs and hind legs adapted for swimming and attached to centers of bodies permitting sudden changes of direction. Larvae, slender, with rather conspicuous abdominal appendages.
Adults commonly fly, often in dancing flocks of great numbers. Larvae mostly in water, but some on land.	Found as adults in air in great numbers in season. Larvae found in water; also the pupae.	Common in ponds and streams but particularly so in standing water.	Most species found in fresh water, although a few live in moist soil or dung.	Swim rapidly in spirals and circles on surface of quiet or rapidly-flowing water.
More than 200 kinds of midges in America, some being found in tide pools as well as in fresh-water.	Adirondack black fly, a pest of northeastern states; the buffalo gnat of the Mississippi Valley, and the turkey gnat of the same region, are good representatives.	Some 300 species of North American diving beetles, ranging in length from less than 1/4 inch to more than 2 inches. The largest family of water beetles.	Range through North America and elsewhere, there being nearly 200 North American species. Most common eastern species is *Hydrophilus obtusatus*, 3/5 inch long.	The larger *Dineutes* has about 15 North American species, and the diminutive *Gyrinus* has some 26 North American species.
Class Hexapoda. Order Diptera. Family Chironomidae. May mate in air; a female may drop a brown mass of about 700 eggs into water. These may hatch in 3 or 4 days into larvae that may require from a month to 2 months or more to reach pupal stage. Then may swim like wrigglers near water surface for a few days before transforming to adults.	Class Hexapoda. Order Diptera. Family Simuliidae. Mate in air in early summer; lay white or yellowish eggs, which become black on rocks washed by current and develop into larvae that stand erect in rapidly-flowing water, often making black blotches on bottom. Pupate under water for about 5 days.	Class Hexapoda. Order Coleoptera. Family Dytiscidae. After mating, around March or April, females may lay 20 to 50 eggs, singly in slits in plants under water. These hatch in about 3 weeks into larvae, which develop 4 or 5 weeks, changing into pupae, which remain buried in earth from 10 to 20 days in summer or longer in winter.	Class Hexapoda. Order Coleoptera. Family Hydrophilidae. After mating, females may lay about 130 yellow eggs enclosed in water-proof, cocoon-like structures attached to plants near surface or floating. Larvae crawl about under water going through at least 2 moults in a month. In late summer, for about 12 days, pass pupal stage in soil.	Class Hexapoda. Order Coleoptera. Family Gyrinidae. May fly from pond to pond. After mating, females lay 1 to many white, cylindrical eggs on submerged plants. These hatch into fierce-looking, slender, flattened, light-colored larvae that finally leave water, spin gray, paper-like cocoons in which a month is spent before transforming.
Food of adults of some species, such as punkies, blood, but of most species this is not the case. Larvae may feed on minute plants or animals of the environment. Some few larvae infest living plant material. Some eat the cases that they make of pond-ooze material.	Food of adult female Adirondack black fly, blood; also of the southern buffalo gnat and the turkey gnat. Males, and the white-stockinged black fly, and others, may be harmless, living on plant juices. Protection by numbers, by inaccessibility of region where larval stage is spent, and by escape.	Food of larvae and of adults, animal matter captured in jaws and sucked into the mouth. Young larvae feed by sucking, even attacking and killing their own kind. In captivity, may be fed on raw beef or on a mixture of cereal, powdered shrimp and ant "eggs" ground together. May destroy fish and fish eggs.	Food of adults, largely decaying vegetation, but some feed on other small animals that may be captured alive. Larvae feed on small animals, frequently sucking through hollow jaws. Adults may fly from pond to pond, often being attracted by lights and falling helplessly to ground. Have a number of parasites.	Food of young and of adults, probably solely animal matter, usually captured at water-surface alive. In captivity, may be fed raw beef on tooth-picks left afloat; not known to feed below the surface. Protection by escape, and in some species possibly by offensive, apple-seed odor given off when captured.
Activities of some definitely associated with light as they may all become active at once, usually late in the day, when they may cause a hum of buzzing wings.	Require well-aerated water. See by night with upper halves of the eyes and by day with the lower halves. Must have well developed sense of locating food.	Adults fly from pond to pond; may be attracted by light. Air held under the hard fore-wings enters through openings on top of abdomen; expelled at surface when stale.	Air taken at surface by extending antennae and folding them back over a bubble of air that is carried beneath and spread over under surface.	Apparently have four eyes, two looking upward and two down, but experiments show that the lower pair do not function and they are but a part of the whole eye.
Some, woodland pests in season, but most in their immature stages are valuable forms of fish food, forming the major diet of many species that are valuable to man.	Some, about the worst insect pests of the woods in early summer, attacking cattle and other domestic animals. All may supply, as larvae, useful food to fishes able to get them. One common species is never known to bite.	Unquestionable enemies of fish and other forms of water life but may themselves serve as fish food. Probably serve as useful checks on multiplication of such animals as mosquitoes and their larvae.	Food for some fishes; scavengers of waste materials; kept in control by unfavorable climatic conditions and by parasites. Larvae eat any animals available in aquaria. Pests in fish hatcheries.	Most interesting scavengers of the water-surface with an abundance of common names indicating that they have attracted general attention. Not known to do any particular harm, and might well figure in mosquito control.

WATER-SCORPION	ELECTRIC-LIGHT BUGS, GIANT WATER-BUGS	WATER-BOATMEN	BACK-SWIMMERS	WATER STRIDERS
Like slender sticks, with front legs modified for grasping. Swimming and walking done with second and third pairs of legs. Filaments at end of body close to form breathing tube that may be thrust up to air. Sucking mouth parts. Not conspicuously colored.	The larger *Lethocerus*, between 2 and 3 inches long, flattened, with short, stout, grasping forelegs and short, stout, piercing beak. Wings folded across the back, the rear portion being flexible. *Belostoma*, about 1 inch long. *Abedus*, with prominent middle keel beneath.	Shaped like blunt-ended boats with hind pair of legs modified for swimming; middle pair, long, slender and with two claws. Males, with asymmetrical four last segments under abdomen. Swim right side up but show air film beneath when seen from below.	Bodies, deep-boat-shaped; backs are held downward, light-colored. Hind legs of *Notonecta* and *Buenoa* flattened for swimming. Eyes, large. Furrow on underside enclosed by hairs forms an air chamber into which air is forced by the hind legs.	Slender-legged bugs with slender bodies. The middle pair of legs the longest, with tips resting lightly on water. Hind pair rest an additional section of leg on water. These two pairs drive them over water surface. Some with short wings, and some wingless adults.
Either in deep water among trash or at surface or even basking in sun and entirely dry.	In water, among trash, or under bark under water. May be found flying about at night or on ground.	Lakes, streams and fresh-water ponds of moving or stagnant water.	*Notonecta* (12 species) float at pond surface. *Buenoa* (6 species) swim slowly under surface.	On the surface of either fresh or salt water, often crowded together in flocks. More common on quiet water.
A slender genus, *Ranatra*, common. A [illegible] inch, flat genus *Nepa*, less common; and an intermediate *Curicta* of the south-central states.	Four common genera in the United States. Some, from Brazil and Guiana, 4 inches long.	Some 55 species in 6 genera in one American check-list of the family.	*Notonecta undulata* general over the United States wherever conditions are suitable.	Some 20 species in America north of Mexico, representing 7 genera. Nine of the species of the genus *Gerris* common in East. Others in West. *Halobates* lives on ocean.
Class Hexapoda. Order Hemiptera. Family Nepidae. Mating act a prolonged one. Eggs laid under water in decayed vegetation or on live plants, inserted in holes. Hatch in 2 to 3 weeks into young which go through 5 stages to adult. About 40 days from egg to adult. Prolific egg layers.	Class Hexapoda. Order Hemiptera. Family Belostomatidae. Mate in water, intermittently with egg laying. In *Abedus* and *Belostoma*, females glue eggs to back of resentful males. Eggs hatch in 1 to 2 weeks by lengthwise split in egg freeing nymphs which cluster at surface, the older eating the younger. Nymph stages of development, 5.	Class Hexapoda. Order Hemiptera. Family Corixidae. Males chirp by rubbing front tarsi against beak or opposite leg. Yellow, top-shaped eggs laid on submerged vegetation, or, in one species, on living crayfish. Young show eye-spots in four days. Stages of nymphs, 5, each more nearly like adult than predecessor.	Class Hexapoda. Order Hemiptera. Family Notonectidae. Mate beneath water in spring. *Notonecta insulata* glues white 2.21 mm. eggs to submerged stems. These hatch in about 5 weeks into young resembling adults but with shorter wings and other differences. Some male back-swimmers make shrill sounds by rubbing certain areas.	Class Hexapoda. Order Hemiptera. Family Gerridae. Mate from early spring through the summer, the males sometimes first cutting off wings of females. Eggs laid on supports at water surface, hatch in about 2 weeks by longitudinal split. Young jump about actively and resemble adults. Nymph stages, 5, each lasting about a week, normally.
Food, other animals, mostly insects that are caught and held by forelegs while juices are sucked out. Prey is caught by lying in wait for it. Protection from enemies by inconspicuous nature. Winter as adults. May chirp, when taken from water, by jerking rigid limbs and with help of a rasp on each shoulder.	Food, animal life varying from insects to fish captured and held by strong forelegs and pierced by beak. Known to vanquish fish 4 times their own length. Protect selves by escape, either by swimming or flight, or by hiding under submerged materials. Breeding period, May to August, a female laying a number of 75-150-egg batches.	Food, ooze and slime almost entirely of plant origin. Winter as adults, although some young have been found in January. May migrate from pond to pond easily, thus easily populating isolated bodies of water. Migrate by flying. Protection, by great number, escape and inconspicuousness.	Food, largely small aquatic animals caught by pursuit and killed by stinging or by holding with legs. Some secrete milky substance from thorax. The stings are sufficiently severe that the animals should be handled with care by humans. Normally they would sting only when held too tightly. In captivity, may be fed mosquito wrigglers.	Food, other insects captured at or near the surface of the water sometimes even by jumping into the air for them. May feed on snails near water edge as a pond dries up, laboring greatly to free snail from the mud but succeeding. Protection, by escape or flight, but may be easily drowned if forced to break through surface of water.
When first brought into strong light avoid it but soon react by going towards it. May hibernate at other times of the year when oxygen content of water is abnormal.	Go towards contacts and towards light at certain times.	Young cannot thrive in boiled water. Are more active on dark days than on bright, and probably are active through the night and through the year.	Unless water is aerated in aquaria the animals can hardly be reared successfully through life history. Some mortality during molting. Nematodes effective enemies.	Some species in early stages can swim about under water, standing submergence in this way for some hours; others cannot stand this. Highly nervous in captivity.
Not of economic importance except as checks on the multiplication of small water life. Interesting because of ways of breathing, of capturing food, of locomotion and of reproduction. May be reared on cockroach nymphs.	Probably not useful except in keeping animal life in check in waterways. May be real pests in fish hatcheries where they may destroy both fish, fish eggs and fish food without themselves contributing enough food to compensate.	Adults and eggs used as food in form of flour, by man and birds, in Egypt and Mexico. Imported for this purpose into England by the ton, each ton equalling about 250 million individuals. Serve as scavengers.	Serve as good checks on such aquatic insects as mosquitoes, which are dangerous to man's interests. Make interesting aquarium pets.	To be reared in aquaria they must be free from disturbance. If kept in a small jar they may dash themselves recklessly against the sides. May be fed dead flies or other insects.

POLLUTANTS

I. Biological - Common domestic sewage, coliform bacteria, algae blooms tend to eliminate the existing biota (plants and animals) and substitute extremely high populations of a few tolerant organisms. Effects to water quality: By O_2 depletion and sludge deposits.

II. Toxic - Mine wastes, pesticides, radiation, etc. These pollutants are lethal to organisms at various concentrations and tend to cause spectacular irruptive mortalities for short periods. If prolonged, a sterile habitat will result. Effects to H_2O quality: By direct lethal effects.

III. Inorganic - Silt. Probably the most widespread pollutant. Effects to water quality: By blanketing with an inert mass and by reducing light penetration.

DETERMINANTS OF WATER QUALITY

I. Pollutants

II. Physical environment

III. Man's concept of quality (services it provides)

SAFETY REQUIREMENTS FOR SWIMMING

1. Water Temp. 78°F and above, Air Temp. 5° warmer
2. Color 30 or less
3. Turbidity - Threshold (less than 5), Max. allowable 20
4. Suspended solids, ppm (50), Max. allowable 100
5. Floating solids, None, Max. allowable --
6. Total dissolved solds, ppm (500), Max. allowable --
7. Toxic metals, ppm (0.1), Max. allowable 5
8. Phenol, ppb (5), Max. allowable 50
9. BOD, ppm (1.5), Max. allowable 3
10. Reaction (pH) 6.8 - 7.2, Max. allowable 6.5 - 8.6
11. D.O., ppm 8, Minimum 6

PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS—1962

(Superseding Standards adopted Feb. 6, 1946)[1]

Standards promulgated by the Public Health Service, U.S. Department of Health, Education, and Welfare, Effective Aprii 5, 1962, for potable water used by carriers subject to the Federal Quarantine Regulations

1. DEFINITION OF TERMS

The terms used in these Standards are as follows:

1.1 *Adequate protection by natural means* involves one or more of the following processes of nature that produces water consistently meeting the requirements of these Standards: dilution, storage, sedimentation, sunlight, aeration, and the associated physical and biological processes which tend to accomplish natural purification in surface waters and, in the case of ground waters, the natural purification of water by infiltration through soil and percolation through underlying material and storage below the ground water table.

1.2 *Adequate protection by treatment* means any one or any combination of the controlled processes of coagulation, sedimentation, absorption, filtration, disinfection, or other processes which produce a water consistently meeting the requirements of these Standards. This protection also includes processes which are appropriate to the source of supply; works which are of adequate capacity to meet maximum demands without creating health hazards, and which are located, designed, and constructed to eliminate or prevent pollution; and conscientious operation by well-trained and competent personnel whose qualifications are commensurate with the responsibilities of the position and acceptable to the Reporting Agency and the Certifying Authority.

1.3 *Certifying Authority* means the Surgeon General of the U.S. Public Health Service or his duly authorized representatives. Reference to the Certifying Authority is applicable only for those water supplies to be certified for use on carriers subject to the Public Health Service Regulations—(42 CFR Part 72).

1.4 The *coliform group* includes all organisms considered in the coliform group as set forth in *Standard Methods for the Examination of Water and Wastewater,* current edition, prepared and published jointly by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation.

1.5 *Health hazards* mean any conditions, devices, or practices in the water supply system and its operation which create, or may create, a danger to the health and well-being of the water consumer. An example of a health hazard is a structural defect in the water supply system, whether of location, design, or construction, which may regularly or occasionally prevent satisfactory purification of the water supply or cause it to be polluted from extraneous sources.

1.6 *Pollution,* as used in these Standards, means the presence of any foreign substance (organic, inorganic, radiological, or biological) in water which tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water.

1.7 *Reporting Agencies* means the respective official State health agencies or their designated representatives.

1.8 *The standard sample for the bacteriological test shall consist of:*

1.81 For the *bacteriological fermentation tube test, five (5) standard portions of either:*

(*a*) *ten milliliters (10 ml)*

(*b*) *one hundred milliliters (100 ml)*

1.82 For the *membrane filter technique, not less than fifty milliliters (50 ml).*

1.9 *Water supply system* includes the works and auxiliaries for collection, treatment, storage, and distribution of the water from the sources of supply to the free-flowing outlet of the ultimate consumer.

2. SOURCE AND PROTECTION

2.1 The water supply should be obtained from the most desirable source which is feasable, and effort should be made to prevent or control pollution of the source. If the source is not adequately protected by natural means, the supply shall be adequately protected by treatment.

2.2 Frequent sanitary surveys shall be made of the water supply system to locate and identify health hazards which might exist in the system. The manner and frequency of making these surveys, and the rate at which discovered health hazards are to be removed, shall be in accordance with a program approved by the Reporting Agency and the Certifying Authority.

2.3 Approval of water supplies shall be dependent in part upon:

(*a*) Enforcement of rules and regulations to prevent development of health hazards;

(*b*) Adequate protection of the water quality throughout all parts of the system, as demonstrated by frequent surveys;

(*c*) Proper operation of the water supply system under the responsible charge of personnel whose qualifications are acceptable to the Reporting Agency and the Certifying Authority;

(*d*) Adequate capacity to meet peak demands without development of low pressures or other health hazards; and

(*e*) Record of laboratory examinations showing consistent compliance with the water quality requirements of these Standards.

2.4 For the purpose of application of these Standards, responsibility for the conditions in the water supply system shall be considered to be held by:

(*a*) The water purveyor from the source of supply to the connection to the customer's service piping; and

(*b*) The owner of the property served and the municipal, county, or other authority having legal jurisdiction from the point of connection to the customer's service piping to the free-flowing outlet of the ultimate consumer.

3. BACTERIOLOGICAL QUALITY

3.1 *Sampling.*

3.11 Compliance with the bacteriological requirements of these Standards shall be based on examinations of samples collected at representative points throughout the distribution system. The frequency of sampling and the location of sampling points shall be established jointly by the Reporting Agency and the Certifying Authority after investigation by either agency, or both, of the source, method of treatment, and protection of the water concerned.

3.12 The minimum number of samples to be collected from the distribution system and examined each month should be in accordance with the number on the graph in Figure I, for the population served by the system. For

[1]Public Health Reports 61: 371-384, March 15, 1946.

the purpose of uniformity and simplicity in application, the number determined from the graph should be in accordance with the following: for a population of 25,000 and under — to the nearest 1; 25,001 to 100,000 — to the nearest 5; and over 100,000 — to the nearest 10.

3.13 In determining the number of samples examined monthly, the following samples may be included, provided all results are assembled and available for inspection and the laboratory methods and technical competence of the laboratory personnel are approved by the Reporting Agency and the Certifying Authority:

(a) Samples examined by the Reporting Agency.

(b) Samples examined by local government laboratories.

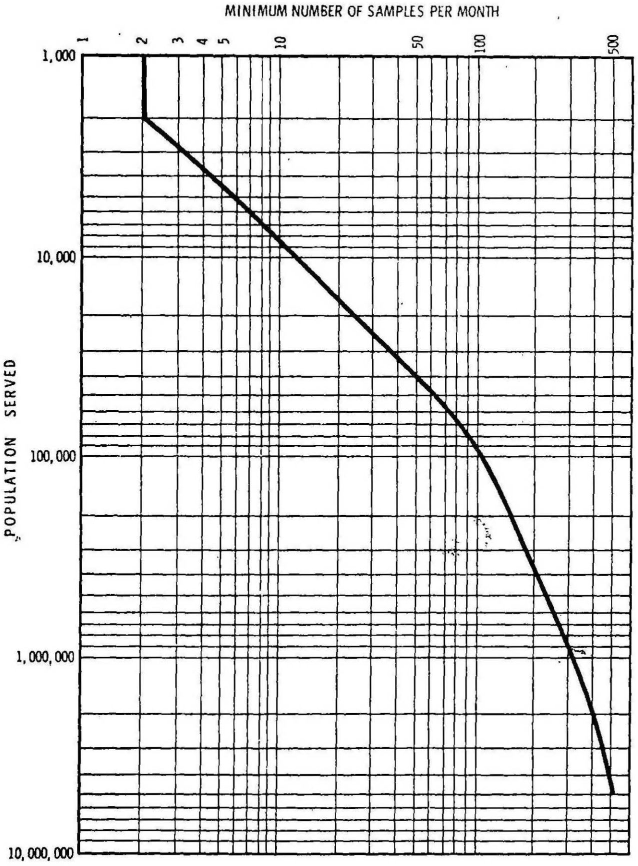


Figure 1

(c) Samples examined by the water works authority.

(d) Samples examined by commercial laboratories.

3.14 The laboratories in which these examinations are made and the methods used in making them shall be subject to inspection at any time by the designated representatives of the Certifying Authority and the Reporting Agency. Compliance with the specified procedures and the results obtained shall be used as a basis for certification of the supply.

3.15 Daily samples collected following a bacteriologically unsatisfactory sample as provided in sections 3.21, 3.22, and 3.23 shall be considered as special samples and shall not be included in the total number of samples examined. Neither shall such special samples be used as a basis for prohibiting the supply, provided that: (1) When waters of unknown quality are being examined, simultaneous tests are made on multiple portions of a geometric series to determine a definitive coliform content; (2) Immediate and active efforts are made to locate the cause of pollution; (3) Immediate action is taken to eliminate the cause; and (4) Samples taken following such remedial action are satisfactory.

3.2 *Limits.* — The presence of organisms of the coliform group as indicated by samples examined shall not exceed the following limits:

3.21 When 10 ml standard portions are examined, not more than 10 percent in any month shall show the presence of the coliform group. The presence of the coliform group in three or more 10 ml portions of a standard sample shall not be allowable if this occurs:

(a) In two consecutive samples;

(b) In more than one sample per month when less than 20 are examined per month; or

(c) In more than 5 percent of the samples when 20 or more are examined per month.

When organisms of the coliform group occur in 3 or more of the 10 ml portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

3.22 When 100 ml standard portions are examined, not more than 60 percent in any month shall show the presence of the coliform group. The presence of the coliform group in all five of the 100 ml portions of a standard sample shall not be allowable if this occurs:

(a) In two consecutive samples;

(b) In more than one sample per month when less than five are examined per month; or

(c) In more than 20 percent of the samples when five or more are examined per month.

When organisms of the coliform group occur in all five of the 100 ml portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

3.23 When the membrane filter technique is used, the arithmetic mean coliform density of all standard samples examined per month shall not exceed one per 100 ml. Coliform colonies per standard sample shall not exceed 3/50 ml, 4/100 ml, 7/200 ml, or 13/500 ml in:

(a) Two consecutive samples;

(b) More than one standard sample when less than 20 are examined per month; or

(c) More than five percent of the standard samples when 20 or more are examined per month.

When coliform colonies in a single standard sample exceed the above values, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

4. PHYSICAL CHARACTERISTICS

4.1 *Sampling.* — The frequency and matter of sampling shall be determined by the Reporting Agency and the Certifying Authority. Under normal circumstances samples

* R-3 WATER QUALITY - FIELD ANALYSIS SHEET

should be collected one or more times per week from representative points in the distribution system and examined for turbidity, color, threshold odor, and taste.

4.2 *Limits.* — Drinking water should contain no impurity which would cause offense to the sense of sight, taste, or smell. Under general use, the following limits should not be exceeded:

* Turbidity	5 units
Color	15 units
Threshold Odor Number	3

5. CHEMICAL CHARACTERISTICS

5.1 *Sampling.*

5.11 The frequency and manner of sampling shall be determined by the Reporting Agency and the Certifying Authority. Under normal circumstances, analyses for substances listed below need be made only semiannually. If, however, there is some presumption of unfitness because of the presence of undesirable elements, compounds, or materials, periodic determinations for the suspected toxicant or material, should be made more frequently and an exhaustive sanitary survey should be made to determine the source of the pollution. Where the concentration of a substance is not expected to increase in processing and distribution, available and acceptable source water analyses performed in accordance with standard methods may be used as evidence of compliance with these Standards.

5.12 Where experience, examination, and available evidence indicate that particular substances are consistently absent from a water supply or below levels of concern, semiannual examinations for those substances may be omitted when approved by the Reporting Agency and the Certifying Authority.

5.13 The burden of analysis may be reduced in many cases by using data from acceptable sources. Judgment concerning the quality of water supply and the need for performing specific local analyses may depend in part on information produced by such agencies as: (1) The U.S. Geological Survey, which determines chemical quality of surface and ground waters of the United States and publishes these data in "Water Supply Papers" and other reports, and (2) The U.S. Public Health Service which determines water quality related to pollution (or the absence of pollution) in the principal rivers of the Nation and publishes these data annually in "National Water Quality Network." Data on pollution of waters as measured by carbon chloroform extracts (CCE) may be found in the latter publication.

5.2 *Limits.* — Drinking water shall not contain impurities in concentrations which may be hazardous to the health of the consumers. It should not be excessively corrosive to the water supply system. Substances used in its treatment shall not remain in the water in concentrations greater than required by good practice. Substances which may have deleterious physiological effect, or for which physiological effects are not known, shall not be introduced into the system in a manner which would permit them to reach the consumer.

5.21 The following chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the Reporting Agency and the Certifying Authority, other more suitable supplies are or can be made available.

Substance	*Concentration in mg/l*
(DETERGENTS) * Alkyl Benzene Sulfonate (ABS)	0.5
Arsenic (As)	0.01
* Chloride (Cl)	250.
* Copper (Cu)	1.
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
* Fluoride (F)	(See 5.23)
* Iron (Fe)	0.3
* Manganese (Mn)	0.05
* Nitrate[1] (NO_3)	45.
Phenols	0.001
* Sulfate (SO_4)	250.
* Total Dissolved Solids	500.
Zinc (Zn)	5.

5.22 The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply:

Substance	*Concentration in mg/l*
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Hexavalent) (Cr^{+6})	0.05
Cyanide (CN)	0.2
Fluoride (F)	(See 5.23)
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

* 5.23 *Fluoride.* — When fluoride is naturally present in drinking water, the concentration should not average more than the appropriate upper limit in Table I. Presence of fluoride in average concentrations greater than two times the optimum values in Table I shall constitute grounds for rejection of the supply.

Where fluoridation (supplementation of fluoride in drinking water) is practiced, the average fluoride concentration shall be kept within the upper and lower control limits in Table I.

TABLE 1.

Annual average of maximum daily air temperatures[1]	Recommended control limits—Fluoride concentrations in mg/l		
	Lower	Optimum	Upper
50.0-53.7	0.9	1.2	1.7
53.8-58.3	0.8	1.1	1.5
58.4-63.8	0.8	1.0	1.3
63.9-70.6	0.7	0.9	1.2
70.7-79.2	0.7	0.8	1.0
79.3-90.5	0.6	0.7	0.8

[1]Based on temperature data obtained for a minimum of five years.

In addition to the sampling required by paragraph 5.1 above, fluoridated and defluoridated supplies shall be sampled with sufficient frequency to determine that the desired fluoride concentration is maintained.

[1]In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

6. RADIOACTIVITY

6.1 *Sampling.*

6.11 The frequency of sampling and analysis for radioactivity shall be determined by the Reporting Agency and the Certifying Authority after consideration of the likelihood of significant amounts being present. Where concentrations of Ra^{226} or Sr^{90} may vary considerably, quarterly samples composited over a period of three months are recommended. Samples for determination of gross activity should be taken and analyzed more frequently.

6.12 As indicated in paragraph 5.1, data from acceptable sources may be used to indicate compliance with these requirements.

6.2 *Limits.*

6.21 The effects of human radiation exposure are viewed as harmful and any unnecessary exposure to ionizing radiation should be avoided. Approval of water supplies containing radioactive materials shall be based upon the judgment that the radioactivity intake from such water supplies when added to that from all other sources is not likely to result in an intake greater than the radiation protection guidance [2] recommended by the Federal Radiation Council and approved by the President. Water supplies shall be approved without further consideration of other sources of radioactivity intake of Radium-226 and Strontium-90 when the water contains these substances in amounts not exceeding 3 and 10 $\mu\mu$c/liter, respectively. When these concentrations are exceeded, a water supply shall be approved by the certifying authority if surveillance of total intakes of radioactivity from all sources indicates that such intakes are within the limits recommended by the Federal Radiation Council for control action.

6.22 In the known absence [3] of Strontium-90 and alpha emitters, the water supply is acceptable when the gross beta concentrations do not exceed 1,000 $\mu\mu$c/liter. Gross beta concentrations in excess of 1,000 $\mu\mu$c/liter shall be grounds for rejection of supply except when more complete analyses indicates that concentrations of nuclides are not likely to cause exposures greater than the Radiation Protection Guides as approved by the President on recommendation of the Federal Radiation Council.

7. RECOMMENDED ANALYTICAL METHODS

7.1 Analytical methods to determine compliance with the requirements of these Standards shall be those specified in *Standard Methods for the Examination of Water and Wastewater,* Am. Pub. Health Assoc., current edition and those specified as follows.

7.2 Barium — *Methods for the Collection and Analysis of Water Samples, Water Supply Paper No. 1454,* Rainwater, F. H. and Thatcher, L. L., U.S. Geological Survey, Washington, D.C.

7.3 Carbon Chloroform Extract (CCE) — *Manual for Recovery and Identification of Organic Chemicals in Water,* Middleton, F. M., Rosen, A. A., and Burttschell, R. H., Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio, *Tentative Method for Carbon Chloroform Extract (CCE) in Water,* J. Am. Water Works A. 54: 223-227, Feb. 1962.

7.4 Radioactivity — *Laboratory Manual of Methodology, Radionuclide Analysis of Environmental Samples, Technical Report R59-6,* Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio; and *Methods of Radiochemical Analysis Technical Report No. 173,* Report of the Joint WHO-FAO Committee, 1959, World Health Organization.

7.5 Selenium — *Suggested Modified Method for Colorimetric Determination of Selenium in Natural Water,* Magin, G. B., Thatcher, L. L. Rettig, S., and Levine, H., J. Am. Water Works Assoc. 52, 1199 (1960).

7.6 Organisms of the coliform group — All of the details of techniques in the determination of bacteria of this group, including the selection and preparation of apparatus and media, the collection and handling of samples and the intervals and conditions of storage allowable between collection and examination of the water sample, shall be in accordance with *Standard Methods for the Examination of Water and Wastewater,* current edition, and the procedures shall be those specified therein for:

7.61 The Membrane Filter Technique, Standard Test, or

7.62 The Completed Test, or

7.63 The Confirmed Test, procedure with brilliant green lactose bile broth,[4] or

7.64 The Confirmed Test, procedure with Endo or eosin methylene blue agar plates.[4]

[2]The Federal Radiation Council, in its Memorandum for the President, Sept. 13, 1961, recommended that "Routine control of useful applications of radiation and atomic energy should be such that expected average exposures of suitable samples of an exposed population group will not exceed the upper value of Range II (20 $\mu\mu$c/day of Radium-226 and 200 $\mu\mu$c/day of Strontium-90)."

[3]Absence is taken here to mean a negligibly small fraction of the above specific limits, where the limit for unidentified alpha emitters is taken as the listed limit for Radium-226.

[4]The Confirmed Test is allowed, provided the value of this test to determine the sanitary quality of the specific water supply being examined is established beyond reasonable doubt by comparisons with Completed Tests performed on the same water supply.

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Table 1. Key Water Criteria for Livestock Use

Characteristic	Recommendations	Page
Total Dissolved Solids (TDS)	< 10,000 mg/l	
Hazardous Trace Elements		
Arsenic	< 0.05 mg/l	
Cadmium	< 0.01 mg/l	
Chromium	< 0.05 mg/l	
Fluorine	< 2.40 mg/l	
Lead	< 0.05 mg/l	
Selenium	< 0.01 mg/l	
Organic Substances		
Algae ("water bloom")	Avoid abnormally heavy growth of blue-green algae	
Parasites and Pathogens	Conform to epidemiological evidence	
Dissolved Organic Compounds	Biological accumulation from environmental sources, including water, shall not exceed established, legal limits in livestock products.	
Radionuclides	Conform to recommendations for Farmstead Water Supplies.	

Table 3. Examples of Fish as Indicators of Water Safety for Livestock (34).

Material	Toxic Levels mg/l for Fish	Toxic Effects on Animals
Aldrin	0.02	3 mg/kg food (poultry)
Chlordane	1.0 (sunfish)	91 mg/kg body wt. in food (cattle)
Dieldrin	0.025 (trout)	25 mg/kg food (rats)
Dipterex	50.0	10.0 mg/kg body wt. in food (calves)
Endrin	0.003 (bass)	3.5 mg/kg body wt. in food (chicks)
Ferban, Fermate	1.0 - 4.0	
Methoxychlor	0.2 (bass)	14 mg/kg alfalfa hay, not toxic (cattle)
Parathion	2.0 (goldfish)	75 mg/kg body wt. in food (cattle)
Pentachlorophenol	0.35 (bluegill)	60 mg/l drinking water not toxic (cattle)
Pyrethrum (allethrin)	2.0 - 10.0	1400-2800 mg/kg body wt. in food (rats)
Silvex	5.0	500-2000 mg/kg body wt. in food (chicks)
Toxaphene	0.1 (bass)	35-110 mg/kg body wt. in food (cattle)

Species. Some interesting species differences also exist among livestock tolerances to water pollutants. A pertinent example of these is the variable response of different types of animals to salinity concentrations. Standards developed in Western Australia as safe upper limits for livestock are listed in Table 4 (14, 15).

Table 4. Proposed Safe Limits of Salinity for Livestock

Animal	Threshold Salinity Concentration* TDS mg/l
Poultry	2860
Swine	4290
Horses	6435
Dairy cattle	7150
Beef cattle	10,000
Sheep (adult, dry)	12,000

*Total salts, mainly NaCl.

These values should not be taken as absolute, but rather interpreted as indicative of the significant species variation that exists. They were developed in a subtropical environment and may not be readily translatable to more temperate areas. Obviously, when feed is also high in salt content, a lower water salinity would be desirable. Moreover, when animals are

INSECTICIDES FISH & AQUATICS

1/10, 1/20 and 1/100 of 48-hour TL_m values from static bioassay, in micrograms per liter.
Exceptions are noted.

Pesticide	Stream Invertebrate [1]				Cladocerans [2]				Fish [3]				Gammarus lacustris [4]		
	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	1/10	1/20	1/100
Abate (R)	Pteronarcys californica	10	5						brook	150	75	15	64	32	6.4
Aldrin[6]	P. californica	0.8	0.4	0.08	D. pulex	2.8	1.4	0.28	rainbow	0.3	0.15	0.03	1,200	600	120
Allethrin	P. californica	2.8	1.4	0.28	D. pulex	2.1	1.05	0.21	rainbow	1.9	0.95	0.19	2	1	0.2
Azodrin(R)									rainbow	700	350	70			
Aramite(R)					D. magna	34.5	17.2	3.45	bluegill	35	17.5	3.5	10	5	1.0
Baygon(R)[6]	P. californica	11	5.5	1.1					fathead	25	12.5	2.5	5	2.5	0.5
Baytex(R)[6]	P. californica	13	6.5	1.3	Simocephalus serrulatus	0.31	0.155	0.031	brown t.	8.0	4.0	0.8	7	3.5	0.7
Benzene Hexa-chloride (Lindane)	P. californica	0.8	0.4	0.08	D. pulex	46	23	4.6	rainbow	1.8	0.9	0.18	8.8	4.4	0.88
Bidrin(R)	P. californica	190	95	19	D. pulex	60	30	6.0	rainbow	800	400	80	79	39.5	7.9
Carbaryl (Sevin (R))	P. californica	1.3	0.65	0.13	D. pulex	0.64	0.32	0.064	brown t.	100[5]	60[5]	10[5]	2.2	1.1	0.22
Carbophenothion (Trithion (R))					D. magna	.0009	.000045	0.00009	bluegill	1.5[5]	0.9[5]	0.15[5]	2.8	1.4	0.28
Chlordane[6]	P. californica	5.5	2.7	0.55	S. serrulatus	2	1	0.2	rainbow	1	0.5	0.1	8	4	0.8
Chlorobenzilate					S. serrulatus	55	27.5	5.5	rainbow	71	35.5	7.1			
Chlorthion(R)					D. magna	.45	.22	0.45							
Coumaphos					D. magna	0.1	0.05	0.01					0.014	0.007	0.0014
Cryolite					D. pulex	500	250	50	rainbow	4,700	2,350	470			
Cyclethrin					D. magna	5.5	2.7	0.55							
DDD (TDE)[6]	P. californica	110	55	11	D. pulex	0.32	0.16	0.032	rainbow	0.9	0.45	0.09	.18	.09	0.018
DDT[6]	P. californica	1.9	0.95	0.19	D. pulex	.036	.018	0.0036	bass	0.21	0.1	0.021	.21	.11	0.021
Delnav (Dioxathion)									bluegill	1.4	0.7	0.14	69	34.5	6.9
Delmeton (Systex(R))						1.4	0.7	0.14	bluegill	8.1	4.0	0.81			
Diazinon[6]	P. californica	6	3	0.6	D. pulex	.09	.045	0.009	bluegill	3	1.5	0.3	50	25	5.0

Pesticide	Stream Invertebrate[1]				Cladocerans[2]				Fish[3]				Gammarus lacustris[4]		
	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	1/10	1/20	1/100
Dibrom(R)(Naled)	P. californica	1.6	0.8	0.16	D. pulex	0.35	0.17	0.035	brook t.	7.8	3.9	0.78	16	8	1.6
Dieldrin[6]	P. californica	.13	.065	0.013	D. pulex	24	12	2.4	bluegill	.34	.17	0.034	100	50	10
Dilan					D. magna	2.1	1.05	0.21	bluegill	1.6	0.8	0.016	60	30	6
Dimethoate (Cygon(R))	P. californica	14	7	1.4	D. magna	250	125	25	bluegill	960	480	96	40	20	4
Dimethrin									rainbow	70	35	7			
Dichlorvos[6] (DDVP)	P. californica	1	0.5	0.1	D. pulex	.007	.0035	0.0007	bluegill	70	35	7	0.1	0.05	0.01
Disulfoten (Di-syston)	P. californica	1.8	0.9	0.18					bluegill	4	2	0.4	7	3.5	0.7
Dursban	Peteronareella badia	.18	.09	0.018					rainbow	2	1	0.2	.04	.02	0.004
Endosulfan (Thiodan)	P. californica	.56	.28	0.056	D. magna	24	12	2.4	rainbow	.12	.06	0.012	.64	.32	0.064
Endrin[6]	P. californica	.08	.04	0.008	D. pulex	2	1	0.2	bluegill	.02	.01	0.002	.47	.24	0.047
EPN					D. magna	.01	.005	0.001	bluegill	1.7	.85	0.17	3.6	1.8	0.36
Ethion	P. californica	1.4	0.7	0.14	D. magna	.007	.0035	0.0007	bluegill	23	11.5	2.3	.32	.16	0.032
Ethyl Guthion(R)[6]					D. pulex	.32	.16	0.032	rainbow	2.3	1.15	0.23			
Fenthion	P. californica	3.9	1.95	0.39	D. pulex	.40	.20	0.04					1.1	0.55	0.11
Guthion(R)[6]	P. californica	0.8	0.4	0.08	D. magna	.02	.01	0.002	rainbow	1	0.5	0.1	.03	.015	0.003
Heptachlor[6]	P. badia	0.4	0.2	0.04	D. pulex	4.2	2.1	0.42	rainbow	0.9	0.45	0.09	10	5	1.0
Kelthane (dicofol(R))	P. californica	300	150	30	D. magna	39	19.5	3.9	rainbow	10	5	1.0			
Kepone(R)									rainbow	2.5[5]	1.5[5]	0.25[5]			
Malathion[6]	P. badia	0.6	0.3	0.06	D. pulex	0.18	0.09	0.018	brook t.	1.95	1	0.195	0.18	0.09	0.018
Methoxychlor[6]	P. californica	0.8	0.4	0.08	D. pulex	.08	.04	0.008	rainbow	0.72	0.36	0.072	0.13	0.07	0.013
Methyl Parathion[6]					D. magna	.48	.24	0.048	bluegill	800	400	80			
Morestan(R)	P. californica	4	2	0.4					bluegill	9.6	4.8	0.96			
Ovex	P. californica	150	75	15					bluegill	70	35	7			
Paradichlorobenzene									rainbow	88	44	8.8			
Parathion[6]	P. californica	1.1	0.55	0.11	D. pulex	.04	.02	0.004	bluegill	4.7	2.35	0.47	0.6	0.3	0.06
Perthane(R)					D. magna	0.94	0.47	0.094	rainbow	0.7	0.35	0.07			
Phosdrin(R)[6]	P. californica	0.9	0.45	0.09	D. pulex	0.016	0.008	0.0016	rainbow	1.7	0.85	0.17	31	15.5	3.1
Phosphamidon	P. californica	46	23	4.6	D. magna	0.4	0.2	0.04	rainbow	800	400	80	0.38	0.19	0.038

Pesticide	Stream Invertebrate[1]				Cladocerans[2]				Fish[3]				Gammarus lacustris[4]		
	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	1/10	1/20	1/100
Pyrethrins	P. californica	0.64	0.32	0.064	D. pulex	2.5	1.2	0.25	rainbow	5.4	2.7	0.54	1.8	0.9	0.18
Rotenone	P. californica	90	45	9	D. pulex	10	5	1.0	bluegill	2.2	1.1	0.22	35	17.5	3.5
Strobane(R)[6]	P. californica	0.7	0.35	0.07					rainbow	0.25	0.13	0.025			
Tetradifon (Tedion(R))									bluegill	110	55	11	14	7	1.4
TETP[6]									fathead	39	19.5	3.9	5.2	2.6	0.52
Thanite (R)					D. magna	450	225	45							
Thimet									bluegill	0.55	0.27	0.055	7	3.5	0.7
Toxaphene[6]	P. californica	0.7	0.35	0.07	D. pulex	1.5	0.75	0.15	rainbow	0.28	0.14	0.028	7	3.5	0.7
Trichlorofon (Dipterex(R))[6]	P. badia	2.2	1.1	0.22	D. magna	.01	.006	0.001	rainbow	160	80	16	5	2.5	0.5
Zectran(R)	P. californica	1.6	0.8	0.16	D. pulex	1	0.5	0.1	rainbow	533[5]	320[5]	53.3[5]	7.6	3.8	0.76

1) Stonefly bioassay was done at Denver, Colorado and at Salt Lake City, Utah. Denver tests were in soft water (35 ppm TDS) non-aerated. Salt Lake City tests were in hard water (150 ppm TDS) aerated. Response was death 48-50 F.

2) Daphnia pulex and Simocephalus serrulatus bioassay was done at Denver, Colorado in soft water (35 ppm TDS), non-aerated 60 F. Daphnia magna bioassay was done at Penn. State Univ. in hard water (146 ppm TDS), 68 F. Response was immobilization.

3) Fish bioassay was done at Denver, Colorado and at Rome, New York. Denver tests were done with 2-inch fish in soft water (35 ppm TDS; pH, 7.2) non-aerated. Rome tests were with 2-2 1/2-inch fish in soft water (6 ppm TA; pH 5.85-6.4), 60 F. Response was death.

4) Gammarus bioassay was done at Denver, Colorado in soft water (35 ppm TDS), non-aerated. Response was death. 60 F.

5) These values are 1/15 and 1/25 of the 48-hour LC_{50} because of the fact that the fish are rendered helpless long before death occurs.

6) Likely to be affected by water quality.

HERBICIDES, FUNGICIDES, DEFOLIANTS, ALGACIDES

1/10 and 1/20 of 48-hour LC_{50} values from static bioassay, in micrograms per liter. Exceptions are Noted.

Pesticides	Stream Invertebrate [1/]				Cladocerans [2/]				Fish [3/]				Gammarus lacustris [4/]		
	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	1/10	1/20	1/100
Ametryne									Rainbow	340	170	34			
Aminotriazole															
Aquathol (R)									Bluegill	25.7	12.8	2.57			
Atrazine					Daphnia magna	360	180	36	Rainbow	1260	630	126			
Azide, potassium									Bluegill	140	70	14	1000	500	100
Azide, sodium									Bluegill	98	49	9.8	900	450	90
Copper chloride									Bluegill	110	55	11			
Copper sulfate									Rainbow	15	7.5	1.5			
Dichlobenil	Pteronarcys californica	4400	2200	440	Daphnia pulex	370	185	37	Bluegill	2000	1000	200	1500	750	150
2,4-D, PGBEE					D. pulex	320	160	32	Rainbow	96	48	9.6	180	90	18
2,4-D, BEE	P. californica	180	90	18					Bluegill	210	105	21	76	38	7.6
2,4-D, Isopropyl									Bluegill	80	40	8			
2,4-D, Butyl Ester									Bluegill	130	65	13			
2,4-D, Butyl + Isopropyl Ester									Bluegill	150	75	15			
2,4,5-T Isooctyl Ester									Bluegill	1670	835	167			
2,4,5-T Isopropyl Ester									Bluegill	170	85	17			
2,4,5-T PGBE									Bluegill	56	28	5.6			
2(2,4-DP) BEE									Bluegill	110	55	11			
Dalapon	P. californica very low toxicity				D. magna	600	300	60	Very low toxicity						
Dead-X	P. californica	500	250	50	D. pulex	370	185	37	Rainbow	940	470	94	560	280	56
DEF	P. californica	280	140	28					Bluegill	24[5/]	14[5/]	2.4[5/]	23	11.5	2.3

Pesticides	Stream Invertebrate [1]				Cladocerans [2]				Fish [3]				*Gammarus lacustris* [4]		
	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	1/10	1/20	1/100
Dexon	P. californica	4200	2100	420					Bluegill	2300	1150	230	600	300	60
Dicamba									non-tox				580	290	58
Dichlone					D. magna	2.6	1.3	0.26	Rainbow	4.8	2.4	0.48	1150	575	115
Difolitan	P. californica	15	7.5	1.5					Channel Cat	3.1	1.5	0.31	650	325	65
Dinitrocresol	P. californica	56	28	5.6					Rainbow	21	10.5	2.1			
Diquat									Rainbow	1230	615	123			
Diuron	P. californica	280	140	28	D. pulex	140	70	14	Rainbow	430	215	43	38	19	3.8
Du-ter (R)									Bluegill	3.3	1.6	0.33			
Dyrene (R)					D. magna	49	24.5	4.9		1.5	0.7	0.15			
Endothal, copper									Rainbow	29	14.5	2.9			
Endothal, dimethylamine									Rainbow	115	57.5	11.5			
Fenac, acid	P. californica	7000	3500	700					Rainbow	1650	825	165			
Fenac, sodium	P. californica	8000	4000	800	D. pulex	450	225	45	Rainbow	750	375	75	1000	900	180
Hydram (R) (Molinate)	P. californica	350	175	35					Rainbow	29	14.5	2.9			
Hydrothol 191									Rainbow	69	34.5	6.9	100	50	10
Lanotan (korax)									Rainbow	10	5	1.0	550	275	55
LFN									Rainbow	7.9	3.95	0.79			
Paraquat	P. californica very low toxicity				D. pulex	370	185	37	Very low toxicity				1800	900	180
Propazine									Rainbow	780	390	78			
Silvex, PGBEE					D. pulex	200	100	20	Rainbow	65	32.5	6.5			
Silvex, isooctyl									Bluegill	140	70	14			
Silvex, BEE									Bluegill	120	60	12			
Simazine	P. californica	5000	2500	500					Rainbow	500	250	50	2100	1050	210
Sodium Arsenite	P. californica Very low				Simocephalus serrulatus	140	70	14	Rainbow	3650	1825	365			
Tordon (picloram)									Rainbow	166[5]	100[5]	16.6[5]	4,800	2,400	480

Pesticides	Stream Invertebrate[1]				Cladocerans[2]				Fish[3]				*Gammarus lacustris*[4]		
	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	Species	1/10	1/20	1/100	1/10	1/20	1/100
Trifuralin	*P. californica*	420	210	42	*D. pulex*	24	12	2.4	Rainbow	1.1[6]	0.55[6]	0.11[5]	560	280	56
Vernam (R) (Vernolate)									Rainbow	393[5]	236[5]	39.3[5]	2,500	1,250	250

1) Stonefly bioassay was done at Denver, Colorado, and at Salt Lake City, Utah. Denver tests were in soft water (35 ppm TDS), non-aerated, 60 F. Salt Lake City tests were in hard water (150 ppm TDS), aerated, 48-50 F. Response was death.

2) *Daphnia pulex* and *Simocephalus serrulatus* bioassay was done at Denver, Colorado, in soft water (35 ppm TDS), non-aerated, 60 F. *Daphnia magna* bioassay was done at Pennsylvania State University in hard water (146 ppm TDS), non-aerated, 68F. Response was immobilization.

3) Fish bioassay was done at Denver, Colorado, and at Rome, New York. Denver tests were with two-inch fish in soft water (35 ppm TDS), non-aerated; trout at 55 F; other species at 65 F. Rome tests were with 2-2 1/2-inch fish in soft water (6 ppm TA: pH 5.85-6.4), 60 F. Response was death.

4) *Gammarus* bioassay was done at Denver, Colorado, in soft water (35 ppm TDS), non-aerated, 60 F. Response was death.

5) These values are 1/15 and 1/25 of the 48-hour LC_{50} because of the fact that the fish are rendered helpless long before death occurs.

6) Becomes bound to soil when used according to directions, but highly toxic (reflected in numbers) when added directly to water.

Effect of Alkyl-Aryl Sulfonate including ABS on Aquatic Organisms.

Organisms	Concentration (mg/l)	Time	Effect	References
Trout	5	26-30 hrs.	death	Wurtz-Arlet, 1960
	3.7	24 hrs.	TL_m	
	5.0	--	gill pathology	Schmid and Mann 1961
Bluegills	4.2	24 hrs.	TL_m	Tumbull, et al., 1954
	3.7	48 hrs.	TL_m	
	0.86	--	safe	
	16.0	30 days	TL_m	Lemke and Mount 1963
	6.5	30 days	gill damage	
	17.0	96 hrs.	TL_m	Cairns and Scheier 1963
Fathead Minnows	2.3	--	Reduced spawning	Pickering, 1966
	13.0	96 hrs.	TL_m	Henderson, et al., 1959
	11.3	96 hrs.	TL_m	Thatcher, 1966
Fathead Minnow Fry	3.1	7 days	TL_m	Pickering, 1966
Pumpkinseed Sunfish	9.8	3 months	gill damage	Cairns and Scheier 1964
Salmon	5.6	3 days	mortality	Holland, et al., 1960
Yellow Bullheads	1.0	10 days	histo-pathology	Bardach, et al., 1965
Emerald Shiner	7.4	96 hrs.	TL_m	Thatcher, 1966
Bluntnose Minnow	7.7	96 hrs.	TL_m	Thatcher, 1966
Stoneroller	8.9	96 hrs.	TL_m	Thatcher, 1966
Silver Jaw	9.2	96 hrs.	TL_m	Thatcher, 1966
Rosefin	9.5	96 hrs.	TL_m	Thatcher, 1966
Common Shiner	17.0	96 hrs.	TL_m	Thatcher, 1966
Carp	18.0	96 hrs.	TL_m	Thatcher, 1966
Black Bullhead	22.0	96 hrs.	TL_m	Thatcher, 1966
"Fish"	6.5	--	Min. lethality	Leclerc and Devlaminck, 1952

(continued).

Organisms	Concentration (mg/l)	Time	Effect	References
Trout Sperm	10	--	Damage	Mann and Schmid 1961
Daphnia	5.0	96 hrs.	TL_m	Sierp and Thiele 1954
	20.0	24 hrs.	TL_m	Godzch, 1961
	7.5	96 hrs.	TL_m	Godzch, 1961
Lirceus fontinalis	10	14 days	6.7% survival (hard water)	Surber & Thatcher 1963
Crangonyx setodactylus[1/]	10	14 days	0% survival (hard water)	Surber & Thatcher 1963
Stenonema area	8	10 days	20-33% survival	Surber & Thatcher 1963
	16	10 days	0% survival	Surber & Thatcher 1963
Stenonema heterotarsale	8	10 days	40% survival	Surber & Thatcher 1963
	16	10 days	0% survival	Surber & Thatcher 1963
Isonychia bicolor	8	9 days	0% survival	Surber & Thatcher 1963
Hydropsychidae (mostly cheumatopsyche)	16	12 days	37-43% survival	Surber & Thatcher 1963
	32	12 days	20% survival	Surber & Thatcher 1963
Orconectes rusticus	16	9 days	100% survival	Surber & Thatcher 1963
	32	9 days	0% survival	Surber & Thatcher 1963
Goniobasis livescens	16	12 days	40-80% survival	Surber & Thatcher 1963
	32	12 days	0% survival	Surber & Thatcher 1963
Snail	18	96 hrs.	TL_m	Cairns and Scheier 1964
	24	96 hrs.	TL_m	Cairns and Scheier 1964

1/ Misidentified originally as Synurella.

(continued).

Organisms	Concentration (mg/l)	Time	Effect	References
Chlorella	3.6	--	slight growth reduction	T. Maloney
"Diatoms"	5.8 23.0	-- --	50% growth 50% growth	Henderson, et al., 1959
Nitzchia linearis	5.8	--	50% reduction in growth in soft water	Cairns, et al., 1964
Navicula seminulin	23	--	50% reduction in growth in soft water	Cairns, et al., 1964

Summary of Specific Quality Characteristics of Raw Waters that have been used as Sources for Industrial Water Supplies.

(Unless otherwise indicated, units are mg/l and values are maximums. No one water will have all the maximum values shown.)

Characteristic	Boiler Make-Up Water		Cooling Water				Process Water							
	Industrial 0-1500 psig	Utility 700-5000 psig	Fresh		Brackish b/		Textile Industry SIC-22	Lumber Industry SIC-24	Pulp & Paper Industry SIC-26	Chemical Industry SIC-28	Petroleum Industry SIC-29	Prim. Metals Industry SIC-33	Food & Kindred Products SIC-20	Leather Industry SIC-31
			Once-Through	Make-up Recycle	Once-Through	Make-up Recycle								
Silica (SiO_2)	150	150	50	150	25	25			50		50			
Aluminum (Al)	3	3	3	3									In general, the quality of raw surface supply should be that prescribed by the NTA Committee on Water Quality Requirements for Public Water Supplies.	
Iron (Fe)	80	80	14	80	1.0	1.0	0.3		2.6	5	15			
Manganese (Mn)	10	10	2.5	10	0.02	0.02	1.0			2				
Copper (Cu)							0.5							
Calcium (Ca)			500	500	1,200	1,200				200	220			
Magnesium (Mg)										100	85			
Sodium & Potassium (Na + K)											230			
Ammonia (NH_3)														
Bicarbonate (HCO_3)	600	600	600	600	180	180				600	480			
Sulfate (SO_4)	1,400	1,400	680	680	2,700	2,700				850	570			
Chloride (Cl)	19,000	19,000	600	500	22,000	22,000			200 a/	500	1,600	500		
Fluoride (F)											1.2			
Nitrate (NO_3)			30	30							8			
Phosphate (PO_4)		50	4	4	5	5								
Dissolved Solids	35,000	35,000	1,000	1,000	35,000	35,000	150		1,080	2,500	3,500	1,500		
Suspended Solids	15,000	15,000	5,000	15,000	250	250	1,000	c/		10,000	5,000	3,000		
Hardness ($CaCO_3$)	5,000	5,000	850	850	7,000	7,000	120		475	1,000	900	1,000		
Alkalinity ($CaCO_3$)	500	500	500	500	150	150				500		200		
Acidity ($CaCO_3$)	1,000	1,000	0	200	0	0						75		
pH, units			5.0-8.9	3.5-9.1	5.0-8.4	5.0-8.4	6.0-8.0	5-9	4.6-9.4	5.5-9.0	6.0-9.0	3-9		
Color, units	1,200	1,200		1,200					360	500	25			
Organics														
Methylene blue active substances	2 d/	10	1.3	1.3		1.3								
Carbon tetrachloride extract	100	100	No floating oil	100	No floating oil	100						30		
Chemical oxygen demand	100	500		100		200								
Hydrogen sulfide (H_2S)					4	4								
Temperature, °F	120	120	100	120	100	120			95 e/			100		

a/ May be ≤ 1,000 for mechanical pulping operations.
b/ Water containing in excess of 1,000 mg/l dissolved solids.
c/ No large particles ≤ 3 mm. diameter.
d/ One mg/l for pressures up to 700 psig.
e/ Applies to bleached chemical pulp and paper only.

NOTE: Application of the above values should be based on analytical methods in ASTM Manual on Industrial Water and Industrial Waste Water (2) or APHA Standard Methods for the Examination of Water and Waste Water (1).

Trace Element Tolerances for Irrigation Waters.

Element	Tolerance for Water used on Type A Land.	Maximum Value of Tolerance Limit for Water used on Type B Land.
	mg/l	mg/l
Aluminum	1.0	20.0
Arsenic	1.0	10.0
Beryllium	0.5	1.0
Boron	0.75	2.0
Cadmium	0.005	0.05
Chromium	5.0	20.0
Cobalt	0.2	10.0
Copper	0.2	5.0
Fluorine	-	-
Iron	-	-
Lead	5.0	20.0
Lithium	5.0	5.0
Manganese	2.0	20.0
Molybdenum	0.005	0.05
Nickel	0.5	2.0
Selenium	0.05	0.05
Tin	-	-
Tungsten	-	-
Vanadium	10.0	10.0
Zinc	5.0	10.0

Levels of herbicides permissible in irrigation water[1/]

Herbicide	Site of use	Type of formulation	Treatment rate	Likely conc. in irrigation water reaching crop or field	Crop injury threshold in irrigation water (mg/l) *	Remarks
Acrolein	In water from cylinders under nitrogen gas pressure.	Soluble liquid	15 mg/l x 4 hrs	10 to 0.1 mg/l	Flood or furrow: beans-60, corn-60 cotton-80, soybeans-20, sugarbeets-60.	Small canals up to 100 cfs conc. reduced to minimum in 10 to 20 miles.
			0.6 mg/l x 8 hrs	0.4 to 0.02 mg/l	Sprinkler: corn-60 soybeans-15 sugarbeets-15	Medium canals, 100 to 500 cfs conc. reduced to min. in 20 to 30 miles.
			0.1 mg/l x 48 hrs	0.05 to 0.1 mg/l		Large canals 1000 cfs and larger conc. to min. in 30 to 50 miles.
Aromatic solvents (xylene)	Emulsified in flowing water.	Emulsifiable liquid	6-10 gal/cfs in 30-60 min. (300-750 cfs)	700 mg/l or less	Alfalfa->1600, beans-1200, carrots-1600, corn-3000, cotton-1600, grain sorghum->800, oats-2400, potatoes-1300, wheat->1200.	Concentration reduced rapidly from point of application within 2 to 6 miles and almost completely in 6 to 10 miles.
Copper sulfate	In flowing water canals or in reservoirs.	Coarse pentahydrate crystals	0.5 to 3.0 mg/l (continuous)	0.8 to 0.04 mg/l in 10 miles	Apparently above concentrations used for weed control.	Concentration reduced more rapidly with distance from slug applications.
			1/3 to 1 lb/cfs (slug)	9.0 to 0.08 mg/l in 10 to 20 miles		

Amitrole-T	On bank weeds along irrigation canals and on cattail in drain canals.	Foliage spray	6 to 16 lb/A	Usually less than 0.1 mg/l**	Beets (Rutabaga)>3.5, corn>3.5	Registered for use only in drain canals and marshes, but actually used for control of bank weeds along western irrigation canals.
Dalapon	On bank weeds along irrigation canals and on cattail in drain canals.	Foliage	15 to 30 lb/A	Usually less than 0.5 mg/l**	Beets->7.0, corn-<.35	Same as for amitrole-T.
Diquat	In water or over surface of canals and reservoirs.	Liquid	3-5 mg/l or 1-1.5 lb/A	Usually less than 0.1 mg/l	Beans-5.0 corn-125.0	Diquat used in Florida for control of submersed weeds and floating weeds. Do not use for 10 days. Not used in western irrigation systems.
Diuron	On bottoms and banks of small canals when no water is in canal.	Wettable powder suspension sprayed	64 lb/A	Below crop injury threshold	No data	Used mostly in small farm ditches with intermittent water flow.
Monuron	Same as for diuron	Same as for diuron	64 lb/A	Below crop injury threshold	No data	Same as for diuron except first water through canal after treatment not used for irrigation.
Endothall Na & K salts	In ponds and reservoirs mostly in eastern states.	Liquid or granule	1-4 mg/l	Probably little or none after waiting period.	Corn-25 field beans-1.0 alfalfa->16.6	Must wait 7 days after treatment before using water for irrigation or domestic purposes.
Dimethyl-amines	In water control canals in Florida. Promising for use in western canals.	Liquid	0.5-2.5 mg/l	Same as for Na and K salts.	Corn->25 soybeans->25 sugarbeets-25	Wait for 7-25 days (depending on concentration) after treatment before using water.

2,4-D	Weeds along canal banks.	Liquid spray	1 to 4 lb/A usually as amine	3.0μg/l to 1.0 μg/l, 2 to 10 mi. below treatment.	Field beans- >3.5 <10 Grapes-0.7-1.5	**Reg. precaution:** Do not contaminate water to be used for irrigation.
	Floating and emersed weeds in southern canals.	Liquid spray	1 to 4 lb/A usually as amine	0.1 mg/l or less to none in 3 weeks.	Sugarbeets-3.5	A minimum waiting period of 3 weeks before using treated water for irrigation.
Silvex	Phreatophytes on flood-ways, along canals, reservoirs, and streams.	Liquid spray as ester	2 to 4 lb/A	No data. Probably less than 0.1 mg/l.	No data.	Silvex registered only for control of aquatic weeds in nonflowing water at 4 lb/100 gal. of water. Do not use in water to be used for agricultural or domestic purposes.
	Floating and emersed aquatic weeds in southern waterways.	Liquid spray over surface.	2 to 8 lb/A	From 10 to 1600 μg/l,1 day after application. 1 to 70 μg/l, 5 wks. after treatment.	No data.	
Dichlobenil	Promising bottom treatments in canals without water.	Granules or wettable powder spray.	7 to 10 lb/A		Alfalfa-10 corn->10 soybeans-1.0 sugarbeets-1.0 to 10	Registered for control of submersed weeds in lakes, ponds, and drainage ditches where water not used for agricultural or domestic purposes.
Fenac	Same as dichlobenil.	Same as dichlobenil.	10 to 20 lb/A	0.66 to 1.8 mg/l below treated area. 0.007 to 0.100 mg/l 2 hrs. later.	Alfalfa-1.0 corn-10 soybeans-0.1 sugarbeets-0.1 to 10	Same as dichlobenil.

Pichloram	For control of brush and weeds on watershed areas.	Liquid spray or granules.	1 to 3 lb/A	No data.	Corn->10 field beans-0.1 sugarbeets-<1.0	Gives excellent control of Canada thistle and other bank weeds, but use near canals hazardous.

1/ Data submitted by F. L. Timmons, Crops Protection Branch, Crops Research Division, ARS, USDA (Unpublished).

* Data are for flood or furrow irrigation for all herbicides except when sprinkler irrigation is indicated for acrolein. Threshold of injury is lowest concentration that caused either temporary or permanent injury. Often this concentration did not cause final reduction in crop yield or quality.

** Estimates based upon very limited data and extensive observations.

·VARIATIONS IN DISSOLVED SOLIDS, CHEMICAL TYPE AND SEDIMENT RIVERS IN ARID AND SEMIARID UNITED STATES

Region	Dissolved Solids Concentrations, mg/l		Prevalent Chemical Type*	Sediment Concentrations, mg/l**	
	From	To		From	To
Columbia River Basin	Less than 100	300	Ca-Mg, C-b	Less than 200	300
Northern California	Less than 100	700	Ca-Mg, C-b	Less than 200	+ 500
Southern California	Less than 100	+2,000	Ca-Mg, C-b; Ca-Mg, S-C	Less than 200	+15,000
Colorado River Basin	Less than 100	+2,500	Ca-Mg, S-C; Ca-Mg, C-b	Less than 200	+15,000
Rio Grande Basin	Less than 100	+2,000	Ca-Mg, C-b; Ca-Mg, S-C	+300	+50,000
Pecos River Basin	100	+3,000	Ca-Mg, S-C	+300	+ 7,000
Western Gulf of Mexico Basins	100	+3,000	Ca-Mg, C-b; Ca-Mg, S-C; Na-P, S-C	Less than 200	+30,000
Red River Basin	Less than 100	+2,500	Ca-Mg, S-C; Na-P, S-C	+300	+25,000
Arkansas River Basin	100	+2,000	Ca-Mg, S-C; Ca-Mg, C-b; Na-P, S-C	+300	+30,000
Platte River	100	+1,500	Ca-Mg, C-b; Ca-Mg, S-C	+300	+ 7,000
Upper Missouri River Basin	100	+2,000	Ca-Mg, S-C; Na-P, C-b; Na-P, C-b	Less than 200	+15,000

* Ca-Mg, C-b Calcium-Magnesium, Carbonate-bicarbonate
Ca-Mg, S-C Calcium-Magnesium, Sulfate-Chloride
Na-P, C-b Sodium-Potassium, Carbonate-bicarbonate
Na-P, S-C Sodium-Potassium, Sulfate-Chloride

** Sediment Concentration = $\frac{\text{Annual Load}}{\text{Annual Streamflow}}$

CONVERSION FACTORS

VOLUME AND CAPACITY EQUIVALENTS

Cubic Inches	Cubic Feet	Cubic Yards	Liters	Quarts Liquid	Gallons U.S. Liq.	Gallons Imperial	Pounds of Water @ 4°C
1	0.0005787	0.00002143	0.016387	0.01732	0.004329	0.003605	0.03613
1,728	1	0.03704	28.32	29.92	7.481	6.229	62.43
46,656	27	1	764.6	807.90	201.97	168.17	1,685.5
61.024	0.035315	0.001308	1	1.057	0.2642	0.220	2.205
57.75	0.03342	0.001238	0.9463	1	0.25	0.2082	2.086
231	0.13368	0.004951	3.785	4	1	0.8327	8.345
277.4	0.16054	0.005946	4.546	4.804	1.201	1	10.022
27.68	0.01602	0.0005933	0.4536	0.4793	0.1198	0.09978	1

FLOW EQUIVALENTS

Gallons per Minute	Thousand Gallons per Hour	Million Gallons per Day	Cubic Feet per Second	Liters per Second
1	0.060	0.001440	0.002228	0.06309
16.67	1	0.024	0.03713	1.052
694.4	41.67	1	1.547	43.81
448.8	26.93	0.6463	1	28.32
15.85	0.951	0.02282	0.03532	1

PRESSURE EQUIVALENTS

Pounds Per Square Inch	Atmospheres	Column of Hg @ 32°F Inches	Columns of Water @ 4°C Inches	Feet	Meters
1	0.06805	2.036	27.68	2.307	0.7031
14.696	1	29.92	406.8	33.90	10.33
0.4912	0.03342	1	13.60	1.133	0.3453
0.03613	0.002458	0.07355	1	0.08333	0.0254
0.4335	0.02950	0.8826	12	1	0.3048
1.422	0.09677	2.896	39.37	3.281	1

MASS EQUIVALENTS

Grams	Ounces Avdp.	Pounds Avdp.	Kilograms	Tons (Short)
1	0.035274	0.0022046	0.0010	0.000001102
28.35	1	0.06250	0.02835	0.00003125
453.6	16	1	0.4536	0.00050
1,000	35.27	2.2046	1	0.001102
907,190	32,000	2,000	907.2	1

LENGTH EQUIVALENTS

Centimeters	Inches	Feet	Meters	Miles Statute
1	0.3937	0.03281	0.010	0.000006214
2.540	1	0.08333	0.02540	0.00001578
30.480	12	1	0.3048	0.0001894
100	39.37	3.281	1	0.0006214
160,930	63,360	5,280	1,609.3	1

AREA EQUIVALENTS

Square Miles Statute	Acres	Square Feet	Square Inches	Square Meters
	640	27,878,000	—	2,590,000
J.001562	1	43,560	6,273,000	4,047.0
—	0.00002296	1	144	0.09290
—	—	0.006944	1	0.0006452
—	0.0002471	10.76	1,550.0	1

TIME EQUIVALENTS

Days	Hours	Minutes	Seconds
1	24	1,440	86,400
0.04167	1	60	3,600
0.0006944	0.01667	1	60
0.00001157	0.0002777	0.01667	1

Temperature Conversion Formulas

Degrees Celsius (formerly Centigrade) C	Degrees Fahrenheit—F	Degrees Réaumur—R
C +273.15 = K Kelvin	F +459.67 = Rankine	R x 5/4 = C Celsius
(C x 9/5) +32 = F Fahrenheit	(F − 32) x 5/9 = C Celsius	(R x 9/4) +32 = F Fahrenheit
C x 4/5 = R Réaumur	(F − 32) x 4/9 = R Réaumur	

°C	−40	−17.8	5	10	15	20	25	30	35	40	45	50	55	60
°F	−40	0	41	50	59	68	77	86	95	104	113	122	131	140

MISCELLANEOUS EQUIVALENTS

1 part per million = 1 mg per liter = 8.34 lbs per million gal
1 grain per gallon = 17.12 part per million = 142.8 lbs per million gal

$$\text{part per million by weight} = \frac{\text{mg/l}}{\text{Sp Gr}}$$

1 grain = 1,000 mg
1 mgd = 5570 cu ft per hr
1 mgd per acre-ft = 0.430 gpm per cubic yd
1 sq-mile-in. = 17.38 million gal
1 in. per hr = 1.01 cfs per acre
1 gram per capita = 2.2 lbs per 1000 population

Settling Tank

1 cm per sec = 21,205 gpd per sq ft
1 cm per sec = 8.47×10^{-3} hr detention per ft of depth
1 acre-ft = 1,613 cu yd = 43,560 cu ft

cfs = cubic feet per second; cfs x 448.8 = gal/min; cfs x 5.4 x 10^6 = lbs/day

g/l = grams/liter; g/l x 1000 = ppm

g/m^2 = grams/square meter; g/m^2 x 8.922 = lbs/acre

ha = hectare; ha x 2.471 = acres

kg = kilograms; kg x 2.2 = pounds

kg/ha = kilograms per hectare; kg/ha x 0.8922 = lbs/acre

μg - at p/l = microgram atoms phosphorus per liter = 31 ppb phosphorous

μg/g = micrograms per gram = ppm

μg/l = micrograms per liter = ppb; μg/l x 10^3 = ppm

mg/g = milligrams/gram; mg/g x 10^3 = ppm

micromoles P/100 grams x 0.31 = ppm

mg% = milligrams percent = milligrams in 100 grams = 1 part in 100,000 parts wet wgt.; mg% x 0.1 = ppm

NO = nitrate; NO_3 x 0.226 = N

ppm x cfs x 5.4 = pounds/day

gal/min x 1,440 = gal/day

85B

2540

Weights and Measures

Metric System

Length

The primary standard of length is the meter, which is the distance between two lines at 0°C on a platinum-iridium bar known as the International Prototype Meter which is deposited at the International Bureau of Weights and Measures.

one angstrom	(Å)	=	0.0000000001	meter
one millimicron	(m)	=	0.000000001	meter
one micron	(μ)	=	0,000001	meter
one millimeter	(mm)	=	0.001	meter
one centimeter	(cm)	=	0.01	meter
one decimeter	(dm)	=	0.1	meter
one meter	(m)	=	1.0	meter
one dekameter	(dkm)	=	10.0	meters
one hectometer	(hm)	=	100.0	meters
one kilometer	(km)	=	1000.0	meters

Weight

The primary unit of weight is the gram which is defined as 1/1000 of the mass of the International Prototype Kilogram of platinum-iridium which is kept at the International Bureau of Weights and Measures.

one microgram	(mcg)	=	0.000001	gram
one milligram	(mg)	=	0.001	gram
one centigram	(cg)	=	0.01	gram
one decigram	(dg)	=	0.1	gram
one gram	(g)	=	1.0	gram
one dekagram	(dkg)	=	10.0	grams
one hectogram	(hg)	=	100.0	grams
one kilogram	(kg)	=	1000.0	grams

Volume

The primary standard of volume is the liter which is the volume of one kilogram of pure water at 4°C and under normal atmospheric pressure.

one microliter	(μl)	=	0.000001	liter
one milliliter	(ml)	=	0.001	liter
one centiliter	(cl)	=	0.01	liter
one deciliter	(dl)	=	0.1	liter
one liter	(l)	=	1.0	liter
one dekaliter	(dkl)	=	10.0	liters
one hectoliter	(hl)	=	100.0	liters
one kiloliter	(kl)	=	1000.0	liters

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To Convert From	To	Multiply by
Angstrom units	centimeters	1×10^{-8}
Angstrom units	inches	3.937×10^{-9}
Angstrom units	microns	0.0001
Atmospheres	dynes/sq cm	1.0133×10^{6}
Atmospheres	mm of mercury	760
Btu (mean)	calories, gram (mean)	251.98
Btu (mean)	foot-pounds	777.98
Btu (mean)	joules (abs)	1054.8
Calories, gram (mean)	btu (mean)	3.9685×10^{-3}
Calories, gram (mean)	foot-pounds	3.0874
Candle power (spherical)	lumens	12.566
Centimeters	angstrom units	1×10^{8}
Centimeters	feet (U.S.)	0.0328
Centimeters	inches (U.S.)	0.3937
Centimeters	miles (U.S., statute)	6.2137×10^{-6}
Cm of mercury at 0°C	atmospheres	0.0132
Centimeters/second	feet/minute	1.9685
Centimeters/second	miles/hour	0.0224
coulombs (int) (1948)	coulombs (abs)	0.999835
Cubic centimeters	cubic feet (U.S.)	3.5314×10^{-5}
Cubic centimeters	cubic inches (U.S.)	0.0610
Cubic centimeters	gallons (U.S.)	2.6417×10^{-4}
Cubic centimeters	milliliters	0.999972
Cubic centimeters	ounces (U.S., fluid)	0.0338
Cubic centimeters	pints (U.S., liquid)	0.0021
Cubic centimeters	quarts (U.S., liquid)	0.0011
Cubic feet (U.S.)	cubic centimeters	28317.016
Cubic feet (U.S.)	liters	28.31625
Cubic feet (U.S.)	quarts (U.S., liquid)	29.922
Cu ft of water (60°F)	pounds	62.37
Cubic inches (U.S.)	cubic centimeters	16.3872
Cubic inches (U.S.)	cubic feet (U.S.)	5.78704×10^{-4}
Cubic meters	cubic feet (U.S.)	35.3144

To Convert From	To	Multiply by
Cubic meters	cubic inches (U.S.)	61023.38
Degrees	circumferences	0.0028
Drams (apothecaries' or troy)	drams (avoirdupois)	2.1943
Drams (avoirdupois)	drams (apothecaries' or troy)	0.4557
Drams (avoirdupois)	grains	27.34375
Drams (avoirdupois)	grams	1.7718
Drams (avoirdupois)	ounces (avoirdupois)	0.0625
Drams (avoirdupois)	pounds (avoirdupois)	0.003906
Drams (U.S., fluid)	cubic centimeters	3.6967
Drams (U.S., fluid)	gallons (U.S.)	9.7656×10^{-4}
Drams (U.S., fluid)	ounces (fluid)	0.125
Faradays	coulombs (abs)	96500
Feet (U.S.)	centimeters	30.4801
Foot-pounds	btu (mean)	0.0012854
Gallons (U.S.)	cubic centimeters	3785.434
Gallons (U.S.)	cubic feet	0.1337
Gallons (U.S.)	gallons (British)	0.8327
Gallons (U.S.)	liters	3.78533
Gallons (U.S.)	minims	61440
Gallons (U.S.)	ounces (U.S., fluid)	128
Gallons (U.S.)	pounds (avoirdupois) of water at 60°F	8.3370
Grains	drams (avoirdupois)	0.03657
Grains	grams	0.0648
Grams	drams (avoirdupois)	0.5644
Grams	grains	15.4324
Grams	ounces (avoirdupois)	0.0353
Grams	pounds (avoirdupois)	0.0022
Horsepower	btu (mean)/hour	2545.08
Horsepower	calories, kg (mean)/min	10.688
Horsepower	kilowatts (g=980.665)	0.7457
Horsepower	watts (g=980.665)	745.70
Inches (U.S.)	centimeters	2.5400

To Convert From	To	Multiply by
Inches (U.S.)	millimeters	25.4001
Joules (abs)	calories, gram (mean)	0.23889
Joules (abs)	ergs	1×10^{7}
Kilograms	pounds (avoirdupois)	2.2046
Kilowatts (abs)	btu (mean)/hour	3413.04
Liters	cubic centimeters	1000.028
Liters	gallons (U.S.)	0.2642
Liters	ounces (U.S., fluid)	33.8143
Liters	pints (U.S., liquid)	2.11336
Meters	feet (U.S.)	3.2808
Meters	inches (U.S.)	39.37
Microns	centimeters	1×10^{-4}
Microns	inches	3.937×10^{-5}
Miles/hour	Centimeters/second	44.7041
Miles/hour	feet/second	1.4667
Milligrams	grains	0.01543
Milligrams	ounces (avoirdupois)	3.5274×10^{-5}
Milligrams	pounds (avoirdupois)	2.20462×10^{-6}
Milliliters	cubic centimeters	1.000028
Milliliters	ounces (U.S., fluid)	0.0338
Milliliters	pints (U.S., liquid)	0.00211
Ounces (U.S., fluid)	gallons (U.S.)	1/128
Ounces (U.S., fluid)	liters	0.0296
Ounces (U.S., fluid)	milliliters	29.5729
Pints (U.S., liquid)	cubic centimeters	473.179
Pints (U.S., liquid)	cubic inches	28.875
Pints (U.S., liquid)	liters	0.4732
Pounds (avoirdupois)	grains	7000
Pounds (avoirdupois)	grams	453.5924
Pounds (avoirdupois)	pounds (troy)	1.2153
Pounds of water (39.2°F)	gallons (U.S.)	0.1198
Quarts (U.S., liquid)	cubic centimeters	946.3586
Quarts (U.S., liquid)	liters	0.9463
Square centimeters	square inches (U.S.)	0.1550

Table of Atomic Weights

The atomic weights listed are those adopted in 1963 by the International Commission on Atomic Weights. They are the most recently announced values at the time of publication.

Name	Symbol	Atomic No.	Atomic Wt.
Actinium	Ac	89	*(227)*
Aluminum	Al	13	26.9815
Americium	Am	95	*(243)*
Antimony	Sb	51	121.75
Argon	Ar	18	39.948
Arsenic	As	33	74.9216
Astatine	At	85	*(210)*
Barium	Ba	56	137.34
Berkelium	Bk	97	*(247)*
Beryllium	Be	4	9.0122
Bismuth	Bi	83	208.980
Boron	B	5	10.811
Bromine	Br	35	79.909
Cadmium	Cd	48	112.40
Calcium	Ca	20	40.08
Californium	Cf	98	*(249)*
Carbon	C	6	12.01115
Cerium	Ce	58	140.12
Cesium	Cs	55	132.905
Chlorine	Cl	17	35.453
Chromium	Cr	24	51.996
Cobalt	Co	27	58.9332
Copper	Cu	29	63.54
Curium	Cm	96	*(247)*
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	*(254)*
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	*(253)*
Fluorine	F	9	18.9984
Francium	Fr	87	*(223)*
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	196.967
Hafnium	Hf	72	178.49
Helium	He	2	4.0026
Holmium	Ho	67	164.930
Hydrogen	H	1	1.00797
Indium	In	49	114.82
Iodine	I	53	126.9044
Iridium	Ir	77	192.2
Iron	Fe	26	55.847
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	*(257)*
Lead	Pb	82	207.19
Lithium	Li	3	6.939
Lutetium	Lu	71	174.97
Magnesium	Mg	12	24.312
Manganese	Mn	25	54.9380
Mendelevium	Md	101	*(256)*
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.183
Neptunium	Np	93	*(237)*
Nickel	Ni	28	58.71
Niobium	Nb	41	92.906
Nitrogen	N	7	14.0067
Nobelium	No	102	*(256)*
Osmium	Os	76	190.2
Oxygen	O	8	15.9994
Palladium	Pd	46	106.4
Phosphorus	P	15	30.9738
Platinum	Pt	78	195.09
Plutonium	Pu	94	*(242)*
Polonium	Po	84	*(210)*
Potassium	K	19	39.102
Praseodymium	Pr	59	140.907
Promethium	Pm	61	*(147)*
Protactinium	Pa	91	*(231)*
Radium	Ra	88	*(226)*
Radon	Rn	86	*(222)*
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.905
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Samarium	Sm	62	150.35
Scandium	Sc	21	44.956
Selenium	Se	34	78.96
Silicon	Si	14	28.086
Silver	Ag	47	107.870
Sodium	Na	11	22.9898
Strontium	Sr	38	87.62
Sulfur	S	16	32.064
Tantalum	Ta	73	180.948
Technetium	Tc	43	*(99)*
Tellurium	Te	52	127.60
Terbium	Tb	65	158.924
Thallium	Tl	81	204.37
Thorium	Th	90	232.038
Thulium	Tm	69	168.934
Tin	Sn	50	118.69
Titanium	Ti	22	47.90
Tungsten	W	74	183.85
Uranium	U	92	238.03
Vanadium	V	23	50.942
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.905
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

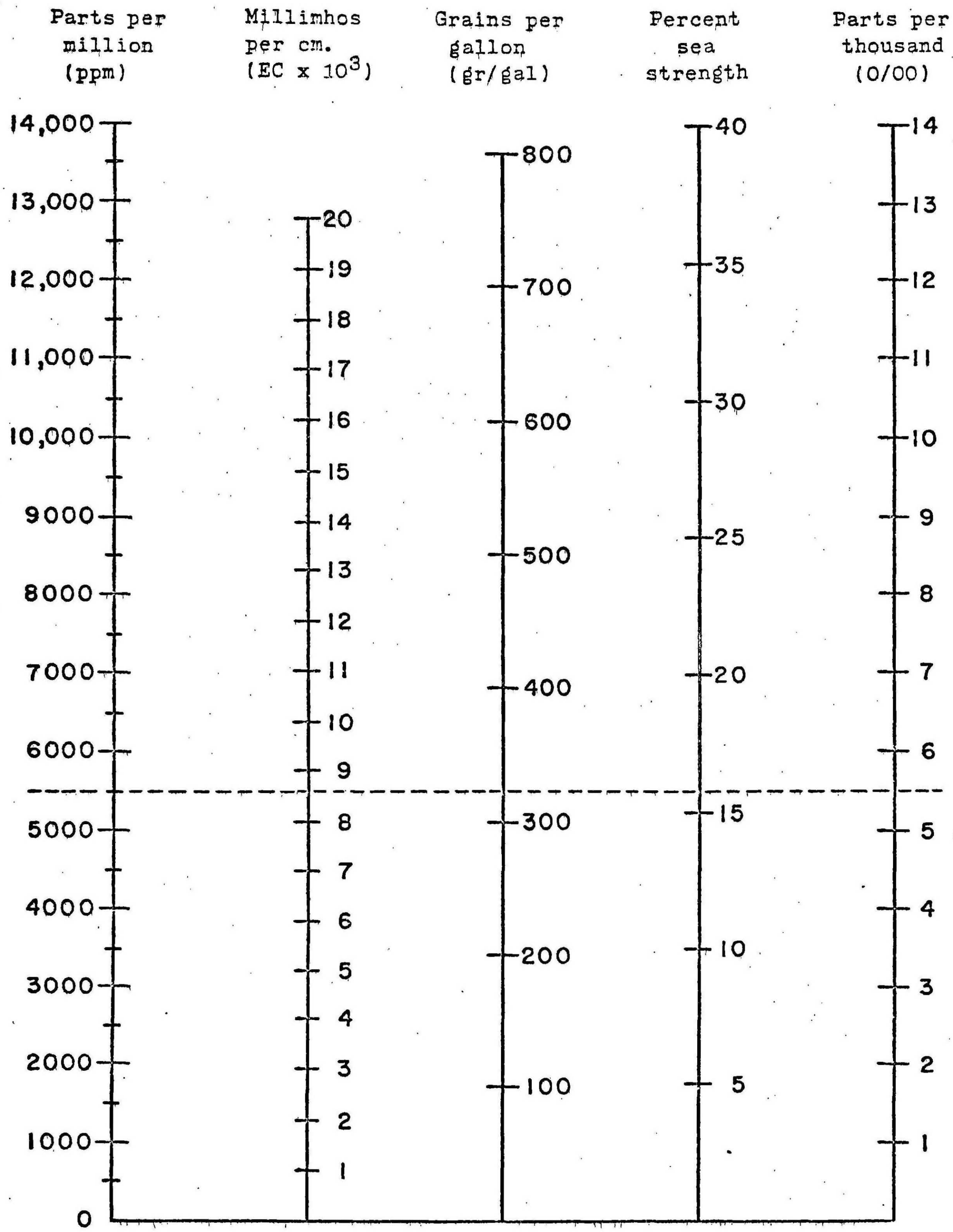

FIGURE 1

CONVERSION OF SEVERAL METHODS OF EXPRESSING SALINITY

With a straight-edge, read across the page. For example, 5,500 ppm is 8.6 millimhos per cm, 320 grains per gallon, 16 percent sea-strength or 5.5 0/00

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2. Water Quality Standards for Streams in Arizona. Arizona State Dept. of Health, 5th Floor, Goodrich Bldg., 14 N. Central Ave., Phoenix, Arizona 85004.

New Mexico Forests

1. Water Resources Data for New Mexico, Part 2. Water Quality Records, USDI, Geological Survey, Water Resources Div., P. O. Box 4217, Albuquerque, New Mexico 87106. (Most recent year)

2. Water Quality Standards for Streams in New Mexico. New Mexico Water Quality Control Commission, State Dept. of Public Health, Santa Fe, New Mexico 87501.